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FUTURE MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS QUALITY AND RETURN FLOW ASPECTS IN THE NECHES, TRINITY, SAN JACINTO, BRAZOS, COLORADO, GUADALUPE, SAN ANTONIO, AND NUECES RIVER BASINS

Public Health Service
Dallas, Texas

January 1962

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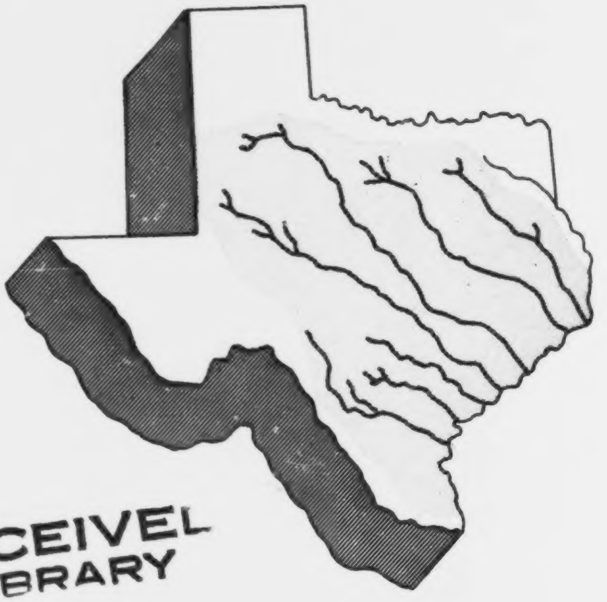
SAN ANTONIO, AND NUECES RIVER BASINS

U. S. STUDY COMMISSION - TEXAS



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WORK ASSIGNMENT 33
by the
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

JANUARY 1962

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
1114 Commerce Street
Dallas 2, Texas

PUBLIC HEALTH SERVICE

January 15, 1962

Mr. Charles D. Curran
Executive Director
U. S. Study Commission - Texas
980 M & M Building
Houston 2, Texas

Dear Mr. Curran:

Transmitted herewith is a supplemental report covering future water requirements for quality control in the rivers of the study area. This was done in compliance with Work Assignment 33 and Memorandum of Understanding 61-4 and includes supporting data for the quality determinations published in the Commission report.

Throughout this report, calculations were made on the critical year forecast for both organic and mineral quality in the various rivers. Although hydrologists have indicated that this critical year will occur no more than 4 percent of the time, it should be realized that augmentation of flows for quality control may be needed during several years prior or subsequent to the critical year. For this reason, augmentation may be needed in some instances during one-third of the years but not necessarily during all months of any of these years.

Caution should be exercised in interpreting these data, not only from the standpoint of overemphasizing the need for quality control water but underemphasizing it as well. If the future industrial and municipal development of these basins is to be reached, an acceptable water must be provided at all times. This report presents the maximum volumes of water needed to reach this goal, for organic and mineral control during the critical year, and the volumes of water needed for mineral control in reservoirs prior to the critical year.

Sincerely yours,

Jerome H Svore

Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control

Encl.

FUTURE MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS
QUALITY AND RETURN FLOW ASPECTS

IN THE

NECHES, TRINITY, SAN JACINTO, BRAZOS, COLORADO
GUADALUPE, SAN ANTONIO, AND NUECES
RIVER BASINS

U. S. STUDY COMMISSION - TEXAS
Work Assignment 33

by the

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

JANUARY 1962

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A-

SYNOPSIS

This report describes the future quality of water for the year 2010 in the United States Study Commission - Texas area and determines the amounts of augmentation water required to maintain the water quality criteria adopted by the Commission.

Under the plan of the Commission all reservoir yields are designated for specific uses with no water provided for water quality control. If water for water quality control is to be made available reallocation of reservoir yields must be made, or water must be imported from outside the study area.

This report is to serve as a guide in determining and locating points and reaches in the eight river basins under study that may need water for water quality control. This report does not specify sources of water to be used for quality control.

The study and analysis of the river basins and adjoining areas show a total need of 827,920 acre-feet of augmentation water to control the deficiency in dissolved oxygen.

Since the source of water for quality control is not known, an investigation outside the study area was made. Indications are that water could be obtained with concentrations of 300 ppm total dissolved solids, or lower. From this investigation it has been decided that two types of water for use in supplementary low flows will be considered in determining water quality control requirements. The difference in these types lies in their concentration of total dissolved solids -- the first containing 300 ppm, and the second, 500 ppm. Selection of these values is based on a general knowledge of water quality of the study area but is unsupported by detailed analyses. Since an actual analysis of the sources has not been made, to reduce the excessive minerals to the required water quality objective, 474,540 acre-feet of water having a total dissolved solids concentration of 300 ppm, or 825,510 acre-feet having a total dissolved solids concentration of 500 ppm will be required. Therefore, the total augmentation need (for dissolved oxygen and mineral solids control) is 1,302,460 acre-feet if augmentation water contains 300 ppm total solids, or 1,653,430 acre-feet if it contains 500 ppm of total dissolved solids.

In the investigation and study several sources of natural and oil field brines were determined. By controlling these sources of mineral pollution a saving in augmentation requirements can be realized. This is especially true in the Brazos basin where a reduction of 17 percent of the total water needs can be realized if gross sources of natural pollution are controlled.

B.

The analysis of the Trinity River basin was made assuming that navigation locks would be placed in the river from Wallisville Reservoir to Fort Worth. The navigation locks cause an increased need for augmentation of approximately two times that required without locks, because of the lowered reairation capacity which will occur in the navigation pools.

Of the total mineral augmentation needs using 300 ppm water, 67 percent, or 319,000 acre-feet can be attributed directly to evaporation on reservoirs. The Brazos River basin alone needs 229,000 acre-feet of the total evaporation augmentation needs. While complete control of evaporation on reservoirs cannot be realized, there is a definite need of eliminating part of this source of water loss.

The augmentation amounts for dissolved oxygen and mineral quality control are shown in Table 1 by river basins for the entire study area.

Table 1

Total Critical Year Forecast of
Augmentation Flows Required
U. S. Study Commission - Texas, River Basins

Basin	Total Augmentation Required (AF/yr.) 300 ppm	Total Augmentation Required (AF/yr.) 500 ppm
Neches	36,300	37,000
Trinity	552,680 [1]	558,580 [1]
San Jacinto [2]	0	0
Brazos	356,200 [3]	611,820 [3]
Colorado	56,200 [4]	86,200 [4]
Guadalupe	72,900	121,650
San Antonio	212,180	212,180
Nueces	16,000 [5]	26,000 [5]
TOTAL	1,302,460	1,653,430

[1] Assuming correction of brine discharges to Richland Creek.

[2] Augmentation for Buffalo Bayou not considered.

[3] Assuming salt water control on Dove Creek and salt correction for Lampasas River.

[4] Assuming elimination of natural pollution from Beals Creek and oil field brines from Bull Creek.

[5] Aransas River in adjoining area.

INTRODUCTION

Authority

This report has been prepared in compliance with U. S. Study Commission - Texas Work Assignment 33 (Work Plan Item F), Second-Stage Planning, Water Quality Analysis of Intrabasin and Areawide Plans, and Memorandum of Understanding 61-4 with supplemental agreements.

Purpose

The purpose of this report is to present results of a study to predict water quality, as indicated by the organic and total dissolved solids content, in all river basins under study as expected under conditions projected to the year 2010 and to determine the amount of additional water that will be needed to maintain stream quality at levels commensurate with criteria of the Commission. These specify that the dissolved oxygen content shall not be less than 4.0 ppm and the total dissolved solids shall not exceed 1,000 ppm in any part of the eight river basins.

Acknowledgments

The assistance and cooperation of representatives of the following are appreciatively acknowledged:

Corps of Engineers, Fort Worth, Texas
Bureau of Reclamation, Austin, Texas
Texas State Department of Health, Austin, Texas
Texas Board of Water Engineers, Austin, Texas

Data and Assumptions Used in Making Quality Determination

Data

1. Existing quality of streams expressed as ppm of total dissolved solids.

2. Municipal and industrial use of each city or area under study and the source of water for such use.

3. Quantity of return flows with organic and mineral loading added to water by user.

4. Quantity of return flows reaching stream or river.
5. Point at which return flows reach river or stream.
6. Mineral load contained in water prior to use.
7. Velocity and temperature of stream or river.
8. Complete operations of river and reservoir which include the following:
    - A. Hydrologic period of drought.
    - B. Conservation storage of reservoir.
    - C. Runoff amounts, broken down into areas or reaches.
    - D. Evaporation amounts on reservoirs for each year of drought and each month of critical year.
    - E. Operation of reservoirs showing amounts and time of diversions to user and for releases downstream.
    - F. Amount, time, and location of diversion for irrigation.
    - G. Amount and location of return flows from irrigation use.
    - H. Content of reservoirs at end of each year of hydrologic period and at end of each month of critical year.

In calculating future water quality and water quality control needs, certain assumptions have been made. These assumptions are listed below.

Assumptions

1. For purposes of comparison, the critical year of the hydrologic period is the same for all basins.
2. The critical year of the hydrologic period will occur under the projected 2010 conditions.

3. Municipal and industrial return flows will be treated to provide 90 percent removal of biochemical oxygen demand and 15 percent removal of minerals.

4. At start of critical period, mineral content of reservoirs, in ppm of total dissolved solids, is equal to runoff.

5. Sediment storage was not available for added capacity to reservoirs by year 2010.

6. Complete mixing takes place in reservoirs for mineral calculations.

7. Reservoirs have self-purification capabilities, with exception of headwaters where polluted streams enter reservoir.

8. All releases downstream are at the temperature of the stream as reflected by existing data and have 1.0 ppm of biochemical oxygen demand.

9. The mineral load in water lost by municipal and industrial use does not return to the stream.

10. The average velocity will remain constant throughout the reach under study and the average temperature will remain constant for the month under study.

11. Irrigation return flows will have the same mineral tonnage as contained in the diverted water, and only project type irrigation will have return flows to the river.

12. Due to the range of 800 ppm to 1,000 ppm of total dissolved solids being questionable and the method of determining total dissolved solids giving an average figure for the period, augmentations are made to correct to 800 ppm of total dissolved solids.

13. Since the source of augmentation water is not known, the assumption is made that such waters will have total dissolved solids concentrations of 300 ppm or 500 ppm.

14. Augmentation will not be provided for polluted streams that have no reservoirs existing or proposed and that are tributaries to main stem rivers.

15. All augmentation would be intercepted in receiving reservoir, provided conservation storage is not exceeded.

Format

Discussion of water quality data in each basin is arrayed in order from the headwaters of the river to the mouth. Tributaries in each basin are listed in order of their occurrence on the main stem of the river.

Water quality discussion is limited to only the reservoirs and reaches of each basin that the analysis shows will be polluted under the year 2010 conditions. Two types of tables are used in the discussion.

1. "Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only" shows by months the minimum amount of dissolved oxygen (DO) in ppm without augmentation for quality and the flow in acre-feet per month (AF/mo.) that will occur at the critical point in the stream, the average monthly augmentation required at this minimum point in acre-feet per month and the total annual augmentation required in acre-feet per year.

2. "Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only" shows by months the maximum mineral concentration in ppm of total dissolved solids without augmentation for quality, and the augmentation required in acre-feet per month of 300 ppm or 500 ppm water for the point or reservoir under study. The release downstream or spills are shown when the conservation storage of the reservoir is exceeded by augmentation.

All analyses of each basin are arrayed on a summary sheet which includes all points studied. The points are listed with the controlling tributary, if any, the critical year of the hydrologic period, and the type of analysis, mineral and/or organic. Under minerals, the total dissolved solids in ppm are for the beginning of the critical year and the increase in total dissolved solids during the year. Where augmentation is provided the total dissolved solids figures are the maximum obtained for any one month during the year; otherwise they are an average for the period. The organic analysis gives the minimum concentration in ppm of dissolved oxygen for the reach and the headwater of a reservoir. In general most reaches studied end at a reservoir and the headwaters are that part of the reservoir where the particular stream under study enters the reservoir. Augmentation is provided for the minimum dissolved oxygen of the reach or headwater, whichever governs. The total augmentation gives the sum of the dissolved oxygen and/or mineral augmentation necessary to satisfy the conditions.

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE NECHES RIVER BASIN

The Neches River rises in Van Zandt County northwest of Tyler and flows generally southeastward 416 miles to Sabine Lake near Beaumont. The main tributary, the Angelina River with a length of 205 miles, joins the main stem of the Neches River at mile 126. The total drainage area of the basin is 9,995 square miles. The fall of the river is over 500 feet and has three breaks in slope with the last 44 miles affected by tidewater.

River Mile	Slope
0 to 44	Tidewater
44 to 270	0.85 ft. per mile
270 to 370	1.15 ft. per mile
370 to 416	4.90 ft. per mile

The present development of the basin consists of nine reservoirs which have capacities greater than 5,000 acre-feet.

The U. S. Study Commission - Texas plan for the basin calls for three new reservoirs and one enlargement of an existing reservoir, Blackburn Crossing. The four new reservoirs are reported to have a combined total yield of 1,845,700 acre-feet per year.

The quality study as presented here consists of individual studies on 6 reservoirs and 10 separate reaches. With the exception of the headwaters of Rockland Reservoir the quality of the water is satisfactory in regard to organic pollution. The return flows from the Lufkin node cause a deficiency of dissolved oxygen and augmentation of 35,200 acre-feet will be required. Lufkin divides its return flow, sending part to the Angelina River. This portion is received in the main body of McGee Bend Reservoir and is sufficiently diluted by the large receiving reservoir; therefore, an analysis of the effect of the pollution to the main body of the reservoir was not considered.

In effect both the Neches River and the Angelina River will receive augmentation water under the proposed plan of development for the year 2010. Blackburn Crossing Reservoir on the Neches River with its enlargement will have a yield, including return flows, of 352,300 acre-feet per year. The operation plan of the reservoir will provide 246,800 acre-feet for municipal and industrial use and 105,500 acre-feet released downstream as spills. This release serves as augmentation downstream to the salt water barrier at river mile 26.5.

Ponta Reservoir is to be operated in the same manner; however, the entire yield of 173,700 acre-feet is to be released downstream to the salt water barrier. The return flows from Henderson and Tyler amounting to 47,400 acre-feet per year are resources to McGee Bend Reservoir.

Rockland Reservoir with a reported yield of 923,400 acre-feet per year will supply the municipal and industrial needs of Area 1D and part of the irrigation needs of Area 1. The remaining portion of the yield, amounting to 722,500 acre-feet, will be released downstream to the salt water barrier. The total amount of 1,001,700 acre-feet serves as augmentation for the reach of the Neches River from Dam "B" river mile 114 to the salt water barrier and is available for interbasin transfer.

Should any change occur in the proposed plan of operation of the reservoirs, reducing the amounts of releases from the reservoirs, a recalculation of the quality in the rivers and reservoirs would be required.

Irrigation needs are confined to Area 1D, and all return flows will return to tidewater, having no effect on the river.

The total augmentation needs of the basin for the critical year in addition to the surplus releases amount to 36,300 acre-feet or 37,000 acre-feet for 300 ppm or 500 ppm water, respectively.

The only critical reach of the Neches River from river mile 354 to river mile 212 flows through Areas 2A and 2B into the headwaters of Rockland Reservoir. In its course, the river collects the return flows from Palestine, Rusk, Jacksonville, Lufkin, and others of Areas 2A and 2B. The total return flows amount to 129,100 acre-feet per year with a biochemical oxygen demand loading of 2,930 tons.

Each city's return flow is assimilated by the river, as it is received, with the dissolved oxygen never dropping below 4.6 ppm until the headwaters of Rockland Reservoir are reached, where the dissolved oxygen drops to 1.9 ppm. During the critical year of 2010 an augmentation of 35,200 acre-feet will be required to maintain the water quality objective of 4.0 ppm of dissolved oxygen. Table 1-Ne shows the augmentation on a monthly basis.

The city of Palestine has a projected return flow of 34,600 acre-feet per year containing 106,610 tons of minerals. The high mineral load will cause the river to exceed the water quality objective of 800 ppm and will require 3,100 acre-feet or 5,150 acre-feet of 300 ppm or 500 ppm water, respectively. Table 2-Ne shows the monthly augmentations necessary to reduce the total dissolved solids to 800 ppm. For the months of August, September, and October the augmentation needs for dissolved oxygen will govern; for the months of November and December augmentation for dissolved oxygen deficiency is not necessary but is necessary for total dissolved solids. The total augmentation needs for the year will include the amounts shown for the months of November and December in Table 2-Ne.

Table 1-Ne

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Neches River

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	7.6	23,950	------
2	8.1	47,940	------
3	6.6	35,500	------
4	7.1	51,650	------
5	6.0	49,540	------
6	3.6	26,050	3,420
7	1.9	20,440	11,970
8	2.1	19,940	9,320
9	2.5	19,540	6,450
10	3.1	19,540	4,000
11	5.0	22,330	------
12	6.8	23,750	------

Total annual augmentation = 35,160 AF/yr.

Table 2-Ne

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Neches River

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	686	-----	-----
2	542	-----	-----
3	589	-----	-----
4	581	-----	-----
5	442	-----	-----
6	716	-----	-----
7	798	-----	-----
8	813	300	500
9	830	700	1,150
10	844	1,000	1,650
11	827	650	1,100
12	818	450	750
TOTAL		3,100	5,150

SUMMARY SHEET
NECHES RIVER BASIN

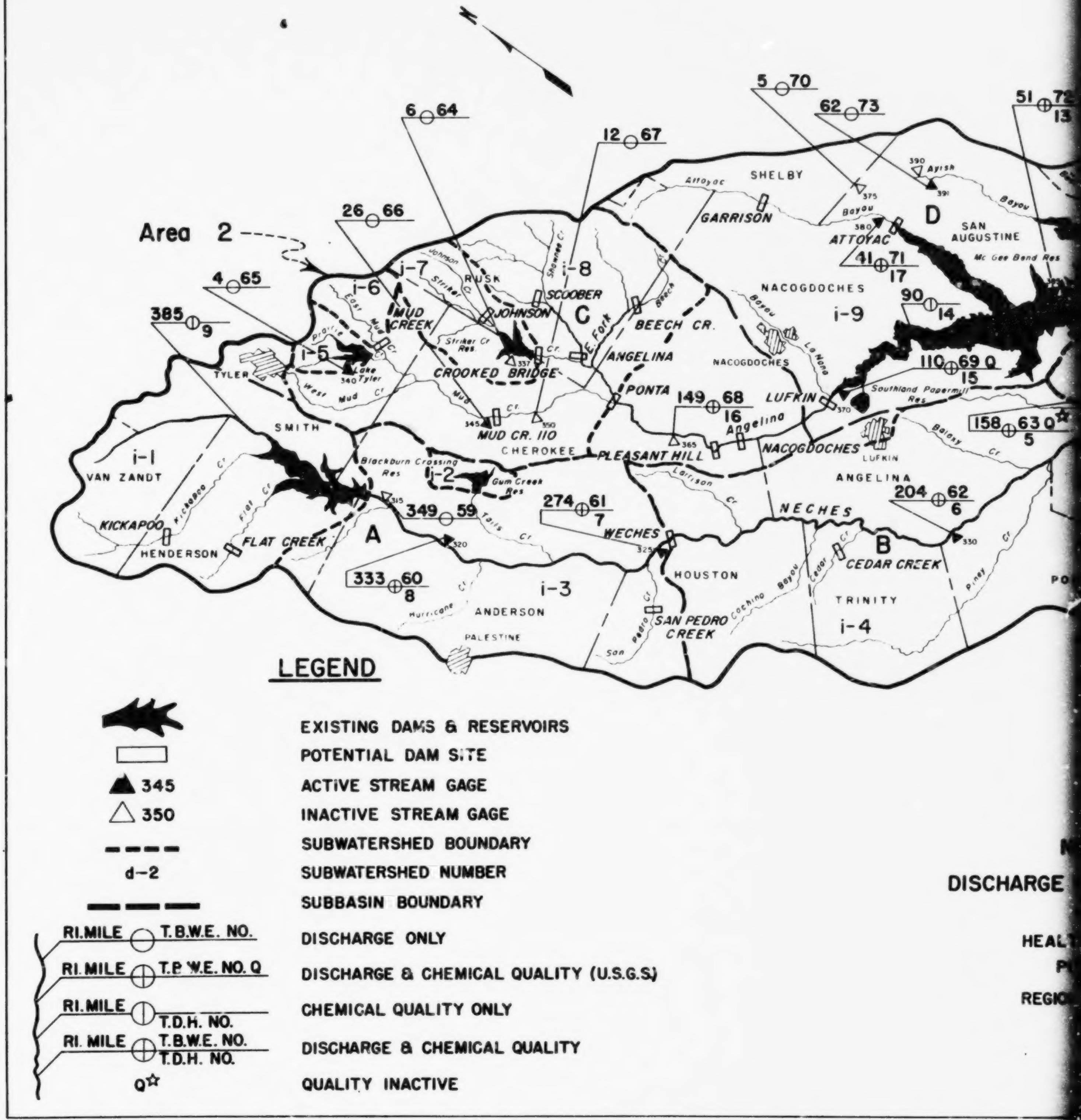
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Minerals: Crit. Year Conc. Start (ppm)	Minerals: Crit. Year Conc. During (ppm)	Minerals: Augmentation Needed 300 ppm (AF/yr)	Minerals: Augmentation Needed 500 ppm (AF/yr)	Dissolved Oxygen: Min. Conc. Reach (ppm)	Dissolved Oxygen: Min. Conc. Head-water (ppm)	Dissolved Oxygen: Augmentation Needed Reach (AF/yr)	Dissolved Oxygen: Augmentation Needed Head-water (AF/yr)	Total Augmentation (DO &/or Mineral) 300 ppm (AF/yr)	Total Augmentation (DO &/or Mineral) 500 ppm (AF/yr)	Remarks
	Butler Creek		M-10 to M-0	1/	--	--	--	--	2.6	0.0	--	--	--	--	Blackburn Crossing headwaters. Augmentation not considered.
Neches			Blackburn Crossing Reservoir, M-354	1/	208	304	--	--	--	--	--	--	--	--	
	Stills Creek		M-16 to M-0	1/	--	--	--	--	4.0	--	--	--	--	--	M-316 on Neches.
	Tails Creek		M-20 to M-0	1/	--	--	--	--	1.2	--	--	--	--	--	M-309 on Neches. Augmentation not considered.
	Boxes Creek		M-20 to M-0	1/	--	--	--	--	2.2	--	--	--	--	--	M-275 on Neches. Augmentation not considered.
	Hurricane Cr.		M-16 to M-0	1/	--	--	--	--	0.3	--	--	--	--	--	M-215 on Neches. Augmentation not considered.
Neches			M-354 to M-212	1/	521	844	3,100	5,150	4.6	1.9	--	35,200	36,300 2/	37,000 2/	Rockland Res. headwater.
Neches			Rockland Res., M-160.4	1/	231	411	--	--	--	--	--	--	--	--	
	Angelina	W. Mud Cr.	M-32 to M-0	1/	--	--	--	--	1.1	0.0	--	--	--	--	Ponta Res. headwaters. Augmentation not considered.
	Angelina	Shawnee Cr.	M-26 to M-1	1/	--	--	--	--	3.6	1.4	--	--	--	--	Ponta Res. headwaters. Augmentation not considered.
	Angelina		Ponta Res., M-168.2	1/	128	145	--	--	--	--	--	--	--	--	
		La Nana	M-16 to M-0	1/	--	--	--	--	3.2	--	--	--	--	--	M-108 on Angelina R. Augmentation not considered.
	Angelina		M-168 to M-106	1/	143	201	--	--	6.6	6.6	--	--	--	--	To McGee Bend headwaters.
	Angelina		McGee Bend Res., M-25	1/	122	163	--	--	--	--	--	--	--	--	
Neches			Dam "B", M-113.7	1/	178	350	--	--	--	--	--	--	--	--	
Neches			Salt Water Barrier M-26.5	1/	169	306	--	--	--	--	--	--	--	--	

	300 ppm (AF/yr)	500 ppm (AF/yr)
Augmentation for Maintenance of Dissolved Oxygen Quality:	35,200	35,200
Augmentation for Maintenance of Mineral Quality:	1,100	1,800
Total:	36,300	37,000

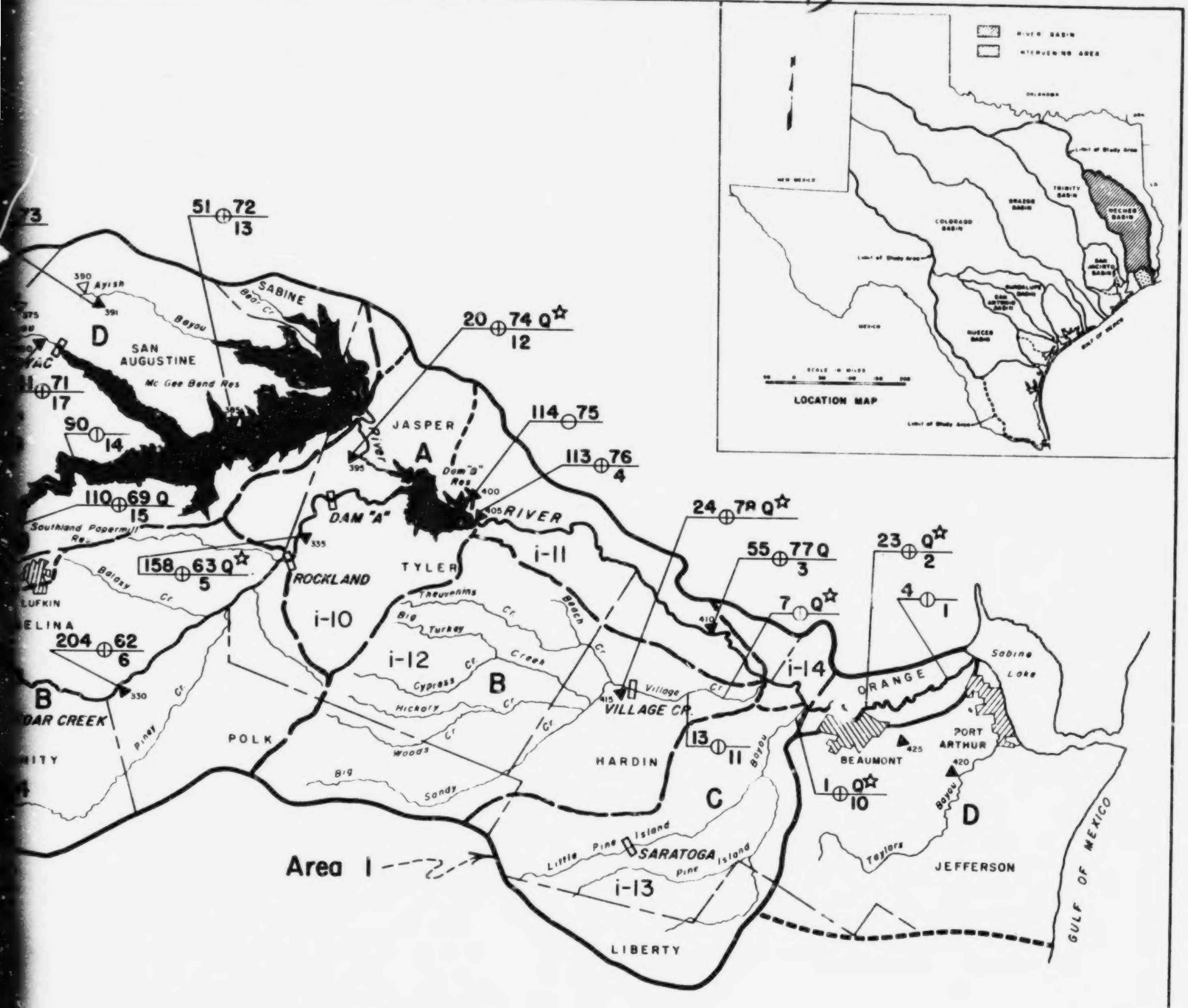
1/ The hydrologic critical year of 1956 projected for 2010 conditions.

2/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

A


Area 2
i-1
i-2
i-3
i-4
i-5
i-6
i-7
i-8
i-9
A
B
C
D
VAN ZANDT
KICKAPOO
HENDERSON
FLAT CREEK
SMITH
TYLER
Lake Tyler
RUSK
MUD CREEK
JOHNSON
SCOOBER
CROOKED BRIDGE
MUD CR. 110
CHEROKEE
Blackburn Crossing Res
Gum Creek Res
PLEASANT HILL
PONTA
ANGELINA
E. Fork
BEECH CR.
GARRISON
SHELBY
ATTOYAC
SAN AUGUSTINE
Mc Gee Bend Res
NACOGDOCHES
LUFKIN
Southland Papermill Res
ANGELINA
NECHES
WECHES
HOUSTON
SAN PEDRO CREEK
CEDAR CREEK
TRINITY
ANDERSON
PALESTINE
385 9
4 65
26 66
6 64
12 67
5 70
62 73
51 72 13
41 71 17
90 14
110 69 Q 15
149 68 16
158 63 Q 5
204 62 6
274 61 7
349 59
333 60 8
LEGEND
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
345 ACTIVE STREAM GAGE
350 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T.B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
N
DISCHARGE
HEAL
P
REGIO

B


LOCATION MAP
RIVER BASIN
INTERVENING AREA
OKLAHOMA
NEW MEXICO
MEXICO
GULF OF MEXICO
COLORADO BASIN
BRAZOS BASIN
TRINITY BASIN
NECHES BASIN
SAN JACINTO BASIN
GUADALUPE BASIN
SAN ANTONIO BASIN
NUECES BASIN
Limit of Study Area
SCALE IN MILES
SABINE
SAN AUGUSTINE
Mc Gee Bend Res
JASPER
TYLER
POLK
HARDIN
LIBERTY
JEFFERSON
ORANGE
BEAUMONT
PORT ARTHUR
Sabine Lake
LUFKIN
ROCKLAND
DAM "A"
Dam "B" Res
RIVER
VILLAGE CR.
SARATOGA
Southland Papermill Res
Area I
A
B
C
D
i-10
i-11
i-12
i-13
i-14
51 72 13
20 74 Q 12
114 75
113 76 4
24 78 Q
55 77 Q 3
23 Q 2
7 Q
4 1
13 11
1 Q 10
110 69 Q 15
158 63 Q 5
204 62 6
90 14
71 17
73
390
391
375
395
400
405
410
415
420
425
335
330
Ayish Bayou
Bear Cr
Angelina
Thevenins Cr
Big Turkey Creek
Cypress Cr
Hickory Cr
Woods Cr
Big Sandy
Beech Cr
Village Cr
Little Pine Island
Pine Island
Bayou
Taylors Bayou
Piney Cr
Balasy Cr
DAR CREEK
ELINA
NITY
GULF OF MEXICO

8 0 8 16 24
SCALE IN MILES

NECHES RIVER BASIN
DISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

NECHES RIVER BASIN

10-A

FIGURE NO. Ne-1

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE TRINITY RIVER BASIN

The Trinity River basin, 17,800 square miles of land, lies in the eastern half of Texas with the Trinity River flowing in a southeasterly direction, entering Galveston Bay at Anahuac. The river is approximately 680 miles long and falls 960 feet over that length. The West Fork joins the Clear Fork at Fort Worth, and the main stem is formed at Dallas by the confluence of the West Fork and the Elm Fork. The major tributaries in the upper reaches are the East Fork, Cedar Creek, and Richland Creek. The profile of the river gives three major breaks in grade.

River Mile	Slope
0 to 60	Tidewater
60 to 260	0.6 ft. per mile
260 to 500	1.1 ft. per mile
500 to 680	3.2 ft. per mile

Under the present development of the basin there are either existing or under construction 27 reservoirs of 5,000 acre-feet or greater capacity.

The U. S. Study Commission - Texas plan for maximum development calls for an addition of 19 new reservoirs of capacities greater than 5,000 acre-feet. The new reservoirs are reported to add a total of 6,619,100 acre-feet of conservation storage to the basin.

To determine the mineral and organic quality of the river and reservoirs, individual studies were made of 31 reservoirs and 8 reaches.

The mineral quality throughout the basin, with a few exceptions, is good. Benbrook Reservoir on the Clear Fork and Bardwell Reservoir on Waxahachie Creek exceed the water quality objective of 800 ppm of total dissolved solids during the critical year of 2010 and will require a total of 6,540 acre-feet or 12,440 acre-feet of 300 ppm or 500 ppm augmentation water. The Richland Creek watershed has a large number of old oil wells that are disposing of their salt brines into the creek. By proper control of these wells Richland Reservoir will have good quality water. The mineral analysis made assumed that such controls would be placed on the oil wells.

The organic study started with the reach between Lake Bridgeport and Eagle Mountain Lake and goes downstream to Tennessee Colony Reservoir. The main source of pollution to the river is the return flow from the Dallas - Fort Worth area. These return flows are sufficient to meet navigation requirements for barge traffic from Wallisville Reservoir to Fort Worth. The proposed plans will place ten locks below Tennessee Colony Reservoir and eleven locks above the reservoir. The navigation locks will reduce the velocity of the river and change the characteristics of the river. The return flows will require 518,250 acre-feet of augmentation per year to maintain the water quality objective of 4.0 ppm of dissolved oxygen.

The reach of the river below Tennessee Colony Reservoir under the proposed plan will be augmented by the releases from Tennessee Colony Reservoir for use downstream and transfer to the Houston metropolitan area. The series of reservoirs in the lower portions of the river, Gail, Mustang, Caney, Long King, and Caper's Ridge, are surplus to the basin's needs and their releases downstream also serve as augmentation to the river, becoming available for interbasin transfer at Wallisville Reservoir. The planned releases from the system of reservoirs in the lower portion of the river will adequately dilute the return flows reaching the river from Tennessee Colony Reservoir to the salt water barrier and additional augmentation will not be required.

Clear Fork

The Clear Fork, a tributary to the West Fork of the Trinity River, flows through Area 4. The reach of the stream between the two existing reservoirs, Lake Weatherford and Benbrook Reservoir, receives the return flows from the city of Weatherford amounting to 6,300 acre-feet per year with a biochemical oxygen demand load of 130 tons per year. During the critical year of 2010 a deficiency in dissolved oxygen occurs at mile 32 and extends into the headwaters of Benbrook Reservoir with the dissolved oxygen dropping to a minimum of 0.0 ppm in the headwaters. An annual augmentation of 4,260 acre-feet will be required to maintain the water quality objective of 4.0 ppm of dissolved oxygen. Table 1-T shows the monthly augmentation needed for the reach.

Table 1-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Clear Fork

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	2.5	460	130
2	2.5	460	130
3	1.5	460	250
4	0.8	460	340
5	5.0	1,570	0
6	0.0	460	740
7	0.0	460	740
8	2.4	760	400
9	0.0	460	740
10	0.3	460	480
11	2.0	460	180
12	2.5	460	130

Total annual augmentation = 4,260 AF/yr.

Benbrook Reservoir

Benbrook Reservoir is located at river mile 15 of the Clear Fork, just west of Fort Worth. The reservoir intercepts drainage from 327 square miles of area and receives the return flow of Weatherford, 6,300 acre-feet per year. Its reported yield amounts to 13,800 acre-feet from a proposed conservation storage of 76,000 acre-feet. The evaporation ranging from 5,300 acre-feet to 13,400 acre-feet per year is the main cause for an excessive mineral concentration. During the critical period the total dissolved solids increase from 420 ppm to 980 ppm and during the critical year of 2010 from 980 ppm to 1,175 ppm. In the period preceding the critical year, augmentation of 8,100 acre-feet or 13,900 acre-feet of 300 ppm or 500 ppm water is required, with an additional amount during the critical year of 3,900 acre-feet or 5,900 acre-feet of 300 ppm or 500 ppm water, respectively.

Table 2-T shows the monthly requirement for augmentation. Dissolved oxygen augmentation upstream as shown on Table 1-T will reduce the required mineral augmentation by 2,100 acre-feet and 2,700 acre-feet per year, depending on whether 300 ppm or 500 ppm of total dissolved solids water is used.

Table 2-T

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Benbrook Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1/] 300 ppm (AF/mo.)	Augmentation [1/] 500 ppm (AF/mo.)
1	984	200	400
2	984	300	600
3	1,040	400	400
4	1,085	1,000	600
5	735	-----	-----
6	824	-----	-----
7	944	-----	-----
8	963	-----	400
9	1,090	1,000	2,000
10	1,175	1,000	1,000
11	1,178	-----	500
12	1,060	-----	-----
TOTAL		3,900	5,900

[1/] It should be noted that the need for augmentations in this case assume that prior to the beginning of the critical year quality was controlled by the addition of 8,100 acre-feet of 300 ppm total dissolved solids water or 13,900 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

East Fork

The East Fork of the Trinity River is located in Area 3 with a total drainage area of 1,441 square miles. The reach of the stream below Forney Reservoir at river mile 32 to its junction with the Trinity River receives the return flows of Garland and Sunnyvale amounting to 35,300 acre-feet per year, with a biochemical oxygen demand load of 444 tons. During the critical year of 2010 a deficiency in dissolved oxygen occurs, dropping to a minimum of 2.0 ppm as it enters the Trinity River at river mile 459. The deficiency in dissolved oxygen will require 10,340 acre-feet of augmentation for the year to maintain the water quality objective of 4.0 ppm. Table 3-T shows the six months of the year that the dissolved oxygen is below 4.0 ppm with the necessary augmentation amount.

Table 3-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, East Fork

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	4.0	2,300	-----
2	4.0	2,300	-----
3	4.0	2,300	-----
4	4.0	2,300	-----
5	3.3	3,220	530
6	2.6	3,220	1,460
7	2.0	3,220	2,590
8	2.0	3,220	2,590
9	2.0	3,220	2,590
10	3.3	3,220	580
11	4.0	2,300	-----
12	4.0	2,300	-----

Total annual augmentation = 10,340 AF/yr.

Kings Creek

Kings Creek, a tributary to Cedar Creek, is located in Area 7 and drains into Cedar Creek Reservoir. The stream receives the return flow of Terrell amounting to 4,400 acre-feet per year with a biochemical oxygen demand load of 90 tons. During the critical year of 2010 the minimum dissolved oxygen is 0.0 ppm requiring 3,800 acre-feet per year of augmentation. Generally this dissolved oxygen deficiency occurs between river mile 66 and river mile 43, above Cedar Creek Reservoir. With augmentation, the stream would reach the reservoir with satisfactory quality water causing no pollution effects on the headwaters of the reservoir. Table 4-T shows monthly requirements for the augmentation.

Table 4-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Kings Creek

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	6.7	1,100	-----
2	9.4	13,810	-----
3	5.9	1,100	-----
4	0.3	410	390
5	7.0	20,900	-----
6	0.0	410	-----
7	0.0	410	1,000
8	0.0	410	1,000
9	0.0	410	790
10	0.0	410	630
11	8.6	10,290	-----
12	6.7	1,100	-----

Total annual augmentation = 3,810 AF/yr.

Waxahachie Creek

Waxahachie Creek, located in Area 6, has an existing reservoir at river mile 25. Below the reservoir the return flows from Waxahachie are received amounting to 5,300 acre-feet per year with a biochemical oxygen demand of 130 tons and flow into Bardwell Reservoir. During the critical year of 2010 a deficiency in dissolved oxygen occurs causing the dissolved oxygen to drop to a minimum of 0.0 ppm in the headwaters of Bardwell Reservoir. A deficiency of this amount will require an augmentation of 2,500 acre-feet per year. Monthly augmentation amounts are shown in Table 5-T.

Table 5-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Waxahachie Creek

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	6.2	560	---
2	7.0	970	---
3	2.7	460	100
4	1.6	460	230
5	3.8	1,270	30
6	1.8	560	320
7	0.0	460	510
8	1.1	560	520
9	0.0	460	510
10	1.0	460	300
11	6.7	1,070	---
12	5.6	560	---

Total annual augmentation = 2,520 AF/yr.

Bardwell Reservoir

Bardwell Reservoir is located in Area 6 at river mile 6 on Waxahachie Creek. The drainage area consists of 140 square miles, with the return flow from Waxahachie adding 5,300 acre-feet per year to the aerial yield of the reservoir. The evaporation ranging from 5,322 acre-feet to 10,287 acre-feet per year causes an increase in total dissolved solids during the critical period. In the period preceding the critical year of 2010 the total dissolved solids increase from 390 ppm to 760 ppm and during the critical year they increase from 760 ppm to a maximum of 1,440 ppm. To reduce the mineral content to the level of 800 ppm of total dissolved solids, 6,500 acre-feet of 300 ppm water will be required. Should 500 ppm water be used as augmentation, 11,000 acre-feet will be required. Table 6-T shows monthly requirements for augmentation. This total augmentation can be reduced by the amount of dissolved oxygen augmention provided upstream and amounts to 1,770 acre-feet during the year.

Table 6-T

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Bardwell Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	749	-----	-----
2	704	-----	-----
3	765	-----	-----
4	821	500	1,000
5	765	-----	-----
6	833	-----	-----
7	1,030	2,500	4,000
8	1,245	2,000	4,000
9	1,412	1,500	2,000
10	1,440	-----	-----
11	1,025	-----	-----
12	991	-----	-----
TOTAL		6,500	11,000

Chambers Creek

Chambers Creek, located in Area 6, flows into Richland Reservoir. In the reach of the creek from river mile 43 to river mile 17 headwaters of Richland Reservoir, it receives the return flows of Ennis and Corsicana amounting to 13,100 acre-feet per year with a biochemical oxygen demand load of 310 tons. During the critical year of 2010 the dissolved oxygen drops to a minimum of 3.1 ppm in the reach and to 0.0 ppm in the headwater of Richland Reservoir. A deficiency of this amount will require 7,000 acre-feet of augmentation during the critical year. Table 7-T shows the monthly breakdown for the augmentation.

Table 7-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Chambers Creek

Month	Critical Point on Reach Without Augmentation for Quality: Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	4.0	1,620	-----
2	4.0	6,230	-----
3	1.3	1,010	500
4	0.3	1,010	770
5	3.9	14,040	*
6	3.7	2,620	*
7	0.0	1,010	1,660
8	1.4	1,620	1,360
9	0.0	1,010	1,660
10	0.0	1,010	1,050
11	4.0	7,330	-----
12	4.0	1,620	-----

Total annual augmentation = 7,000 AF/yr.

*Augmentation is not needed; dissolved oxygen goes to 4.0 ppm and above immediately due to runoff.

Trinity River

The reach of the Trinity River under study includes part of the West Fork from river mile 519 at Fort Worth to river mile 506, junction of the West Fork and Elm Fork with the Trinity River at Dallas, continuing downstream to river mile 384, headwaters of the Tennessee Colony Reservoir. In this distance of 135 miles the river flows through part of Area 4, all of Area 5, and part of Area 7 and receives a combined return flow from the Dallas - Fort Worth area of 653,900 acre-feet per year with a total biochemical oxygen demand load of 19,900 tons.

The entire river from Fort Worth to Wallisville Reservoir will be controlled by navigation locks, causing the river to fall in the classification of a slow or low velocity river. The increased time of flow allows the river to recover itself by the time it reaches the headwaters of Tennessee Colony Reservoir.

During the critical year of 2010 the deficiency in dissolved oxygen occurs in the reach dropping to a minimum of 0.0 ppm, regaining to 7.1 ppm in the headwaters of Tennessee Colony Reservoir as it flows through the 11 proposed locks.

To maintain the water quality objective of 4.0 ppm of dissolved oxygen an augmentation of 518,250 acre-feet per year will be required. Table 8-T gives monthly requirements for this augmentation.

Table 8-T

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Trinity River

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	3.3	28,080	2,760
2	2.5	29,460	12,250
3	1.5	28,360	22,560
4	0.7	29,740	35,730
5	1.1	36,460	32,130
6	0.0	28,630	65,000
7	0.0	27,620	90,310
8	0.0	27,900	88,000
9	0.0	27,620	90,310
10	0.0	28,080	50,480
11	1.6	28,630	21,200
12	3.0	28,360	7,520

Total annual augmentation = 518,250 AF/yr.

SUMMARY SHEET
TRINITY RIVER BASIN

River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Minerals: Crit. Year Conc.: Start (ppm)	Minerals: Crit. Year Conc.: During (ppm)	Minerals: Augmentation Needed: 300 ppm (AF/yr)	Minerals: Augmentation Needed: 500 ppm (AF/yr)	Dissolved Oxygen: Min. Conc.: Reach (ppm)	Dissolved Oxygen: Min. Conc.: Head-water (ppm)	Dissolved Oxygen: Augmentation Needed: Reach (AF/yr)	Dissolved Oxygen: Augmentation Needed: Head-water (AF/yr)	Total Augmentation (DO &/or Minerals): 300 ppm (AF/yr)	Total Augmentation (DO &/or Minerals): 500 ppm (AF/yr)	Remarks
	W. Fork Trinity		Lake Bridgeport M-626	1/	451	509	--	--	--	--	--	--	--	--	
	W. Fork Trinity		M-624 to M-599	1/	--	--	--	--	6.4	6.5	--	--	--	--	Headwater Eagle Mt. Lake.
	W. Fork Trinity		Eagle Mt. Lake, M-583	1/	640	670	--	--	--	--	--	--	--	--	TDS average for period.
		Clear Fork	Lake Weatherford M-40	1/	684	698	--	--	--	--	--	--	--	--	TDS average for period.
		Clear Fork	M-32 to M-17	1/	--	--	--	--	3.2	0.0	--	4,260	4,260	4,260	Headwater Benbrook Res.
		Clear Fork	Benbrook Res., M-15	1/	980	1,175	3,900	5,900	--	--	--	--	1,800 2/	3,200 2/	Added 8,100 AF of 300 ppm prior to critical year or added 13,900 AF of 500 ppm prior to critical year. DO augmentation reduces mineral augmentation.
		Village Cr.	Lake Arlington, M-8	1/	402	485	--	--	--	--	--	--	--	--	TDS average for period.
		Mountain Cr.	Lakeview Res., M-7	1/	412	503	--	--	--	--	--	--	--	--	TDS average for period.
	Elm Fork		Aubrey Res., M-60	1/	431	555	--	--	--	--	--	--	--	--	TDS average for period.
	Elm Fork		Garza Little Elm Res., M-30	1/	470	575	--	--	--	--	--	--	--	--	TDS average for period.
		Denton Cr.	Grapevine Res., M-12	1/	458	552	--	--	--	--	--	--	--	--	TDS average for period.
	East Fork		Lake Lavon, M-56	1/	346	418	--	--	--	--	--	--	--	--	TDS average for period.
	East Fork		Forney Res., M-32	1/	364	476	--	--	--	--	--	--	--	--	TDS average for period.
	East Fork and	Duck Cr.	M-37 to M-0	1/	--	--	--	--	2.0	--	10,340	--	10,340	10,340	6 mi. up Duck Creek. M-0 = M-459, Trinity River.
	Cedar Cr.	Kings Cr.	Terrell Res.	1/	358	580	--	--	--	--	--	--	--	--	
	Cedar Cr.	Kings Cr.	M-66 to M-43	1/	--	--	--	--	0.0	0.0	3,800	3,800	3,800	3,800	Headwater, Cedar Creek Res.
	Cedar Cr.		Cedar Cr. Res., M-10	1/	153	210	--	--	--	--	--	--	--	--	TDS average for period.

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

2/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

SUMMARY SHEET (Continued)
TRINITY RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	Richland Cr.		Navarro Mills Res. M-64	1/	430	404	--	--	--	--	--	--	--	--	TDS average for period.
		Waxahachie Cr.	Waxahachie Res.,M-25	1/	404	580	--	--	--	--	--	--	--	--	TDS average for period.
		Waxahachie Cr.	M-31 to M-6	1/	--	--	--	--	2.8	0.0	--	2,500	2,500	2,500	Headwater Bardwell Res.
		Waxahachie Cr.	Bardwell Res.,M-6	1/	760	1,440	6,500	11,000	--	--	--	--	4,730 2/	9,230 2/	DO augmentation reduces mineral augmentation.
		Chambers Cr.	M-43 to M-17	1/	--	--	--	--	3.1	0.0	--	7,000	7,000	7,000	Headwater Richland Res.
	Richland Cr.		Richland Res.	1/	398	466	--	--	--	--	--	--	--	--	TDS average for period.
	Tehuacana Cr.		Tehuacana Res.	1/	354	418	--	--	--	--	--	--	--	--	TDS average for period.
	Richland Cr. (Tehuacana Cr.(		Richland Res. (Comb. Tehuacana Res.(	1/	390	454	--	--	--	--	--	--	--	--	TDS average for period.
Trinity & West Fork			M-519 to M-384	1/	--	548	--	--	0.7	7.7	518,250	--	518,250	518,250	Headwater Tenn. Col. Res.
Trinity			Tennessee Colony Res., M-340	1/	520	574	--	--	--	--	--	--	--	--	TDS average for period.
	Upper Keechi R.		Upper Keechi Res.	1/	382	419	--	--	--	--	--	--	--	--	TDS average for period.
	Hurricane Bayou		Hurricane Res.	1/	467	559	--	--	--	--	--	--	--	--	TDS average for period.
	Lower Keechi R.		Lower Keechi Res.	1/	393	430	--	--	--	--	--	--	--	--	TDS average for period.
	Bedias Cr.		Bedias Reservoir	1/	360	400	--	--	--	--	--	--	--	--	TDS average fpr period.
	Harmon Cr.		Harmon's Res.	1/	359	438	--	--	--	--	--	--	--	--	TDS average for period.
	White Rock Cr.		Gail Res., M-25	1/	277	324	--	--	--	--	--	--	--	--	TDS average for period.
		Mustang Cr.	Mustang Res.	1/	285	320	--	--	--	--	--	--	--	--	TDS average for period.
		Caney Cr.	Caney Reservoir	1/	253	248	--	--	--	--	--	--	--	--	TDS average for period.
	Long King Cr.		Long King Res.	1/	251	266	--	--	--	--	--	--	--	--	TDS average for period.

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

2/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

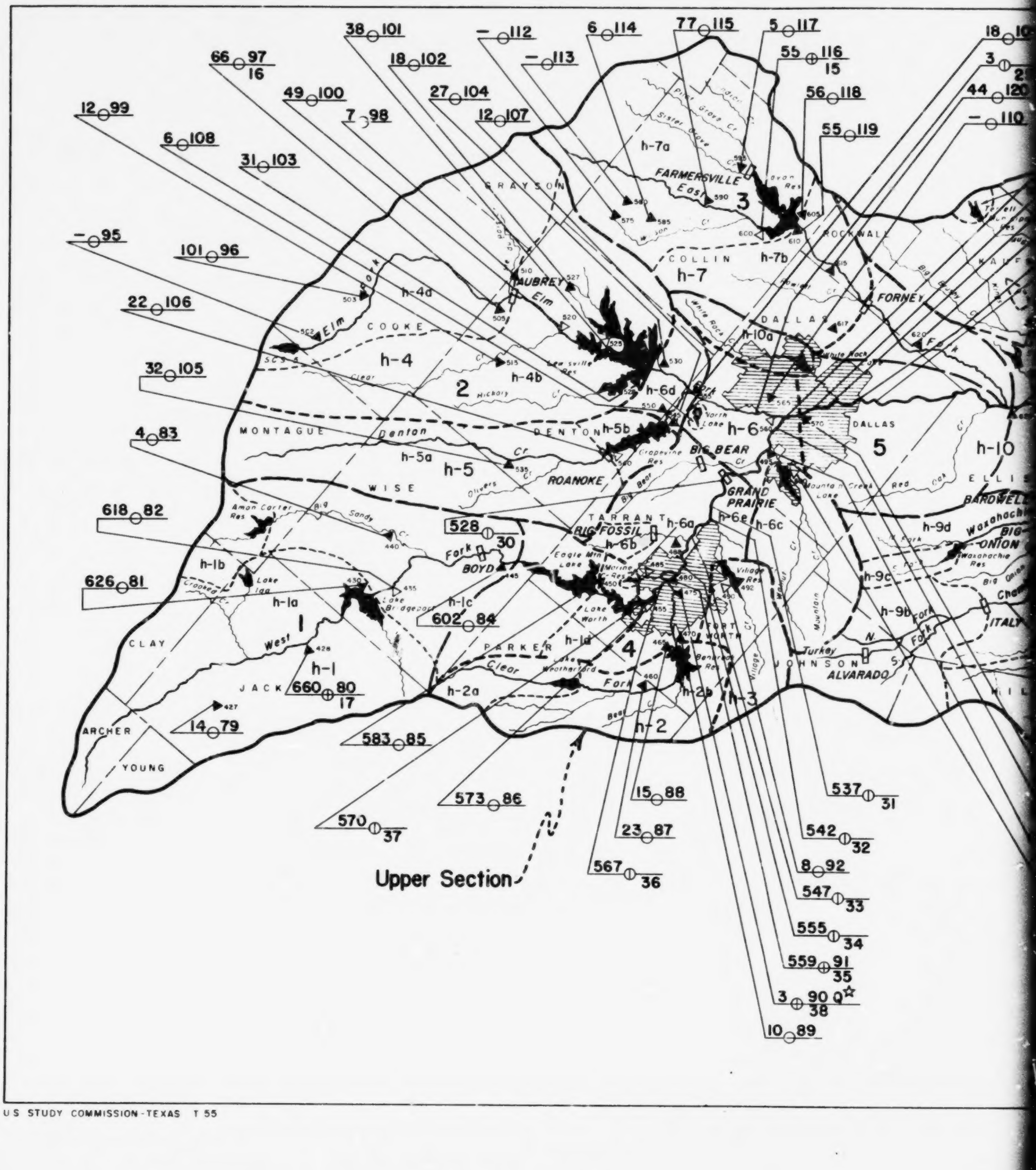
SUMMARY SHEET (Continued)
TRINITY RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
Trinity			M-340 to M-140	1/	--	623	--	--	--	--	--	--	--	--	Headwater Livingston Res.
Trinity			Livingston Res. M-129	1/	404	490	--	--	--	--	--	--	--	--	TDS average for period.
Trinity			Caper's Ridge Res., M-63	1/	378	473	--	--	--	--	--	--	--	--	TDS average for period.
Trinity			Wallisville Res. M-4	1/	406	508	--	--	--	--	--	--	--	--	TDS average for period.

Augmentation for Maintenance of Dissolved Oxygen Quality:	546,150	546,150
Augmentation for Maintenance of Mineral Quality:	6,530	12,430
Total:	552,680	558,580

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

A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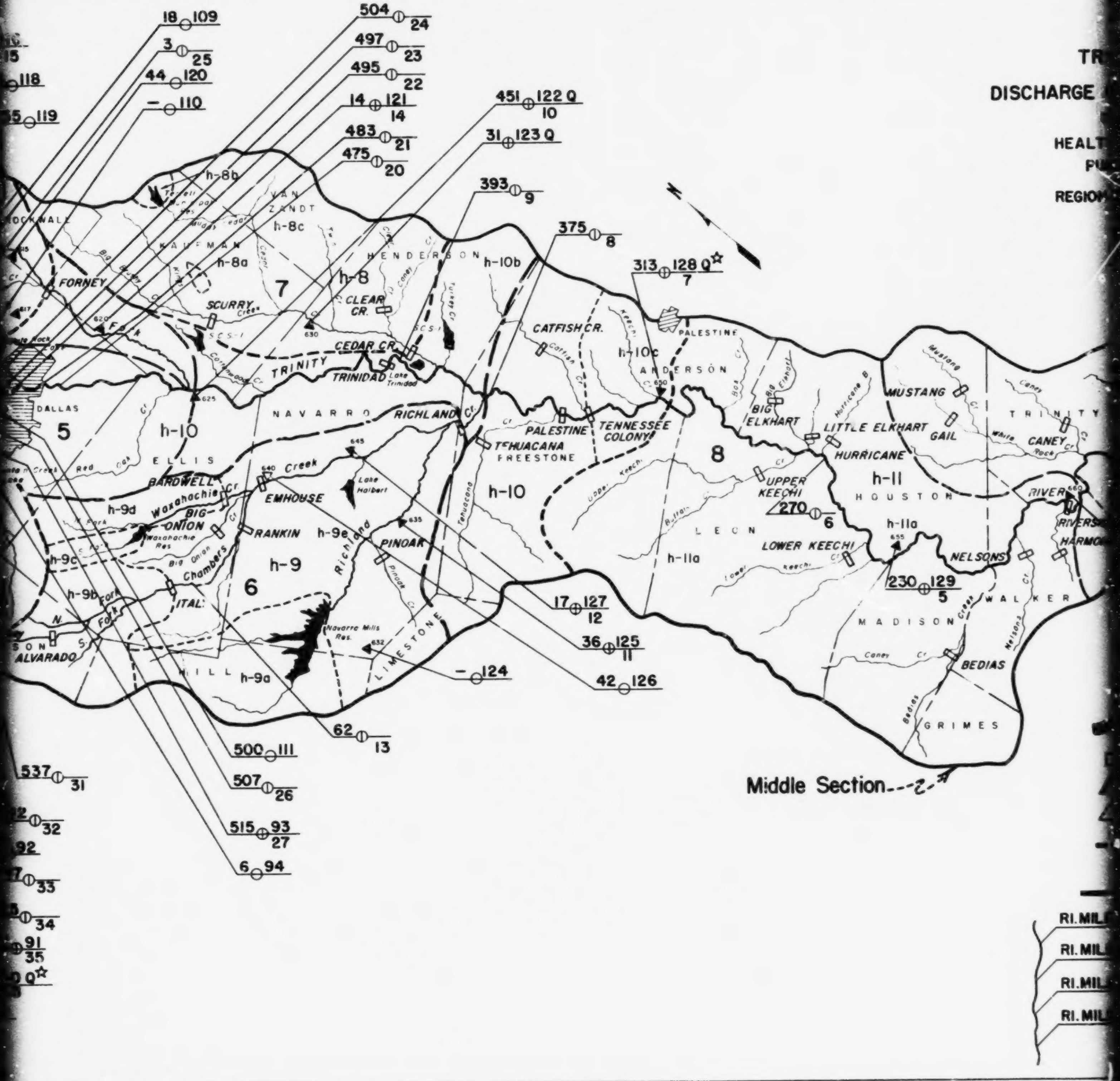
66 97 16
38 101
18 102
49 100
7 98
27 104
12 107
– 112
– 113
6 114
77 115
5 117
55 116 15
56 118
55 119
18 10
3 2
44 120
– 110
6 108
31 103
– 95
101 96
22 106
32 105
4 83
618 82
626 81
528 30
602 84
660 80 17
14 79
583 85
573 86
570 37
15 88
23 87
567 36
537 31
542 32
8 92
547 33
555 34
559 91 35
3 90 Q ☆ 38
10 89
Upper Section
GRAYSON
COLLIN
ROCKWALL
KAUF
DALLAS
COOKE
DENTON
MONTAGUE
WISE
TARRANT
PARKER
JACK
CLAY
ARCHER
YOUNG
JOHNSON
ELLIS
HIL
FARMERSVILLE
AUBREY
ROANOKE
BIG BEAR
GRAND PRAIRIE
BIG FOSSIL
BOYD
FORNEY
ALVARADO
ITALY
BARDWELL
BIG ONION
FORT WORTH
h-1
h-1a
h-1b
h-1c
h-1d
h-2
h-2a
h-2b
h-3
h-4
h-4a
h-4b
h-5
h-5a
h-5b
h-6
h-6a
h-6b
h-6c
h-6d
h-6e
h-7
h-7a
h-7b
h-9b
h-9c
h-9d
h-10
h-10a
1
2
3
4
5
Elm Fork
Clear Fork
West Fork
Denton Cr
Hickory Cr
Big Sandy Cr
Lewisville Res
Grapevine Res
Lake Bridgeport
Eagle Mtn Lake
Lake Worth
Lake Weatherford
Benbrook Res
Amon Carter Res
Lake Lag
White Rock
Mountain Creek Lake
Lavon Res
Waxahachie Res
North Lake
Marine Res
Village Res
Red Oak
Turkey
Sister Grove Cr
East
Olivers Cr
Crooked Cr
SCS

US STUDY COMMISSION-TEXAS T 55

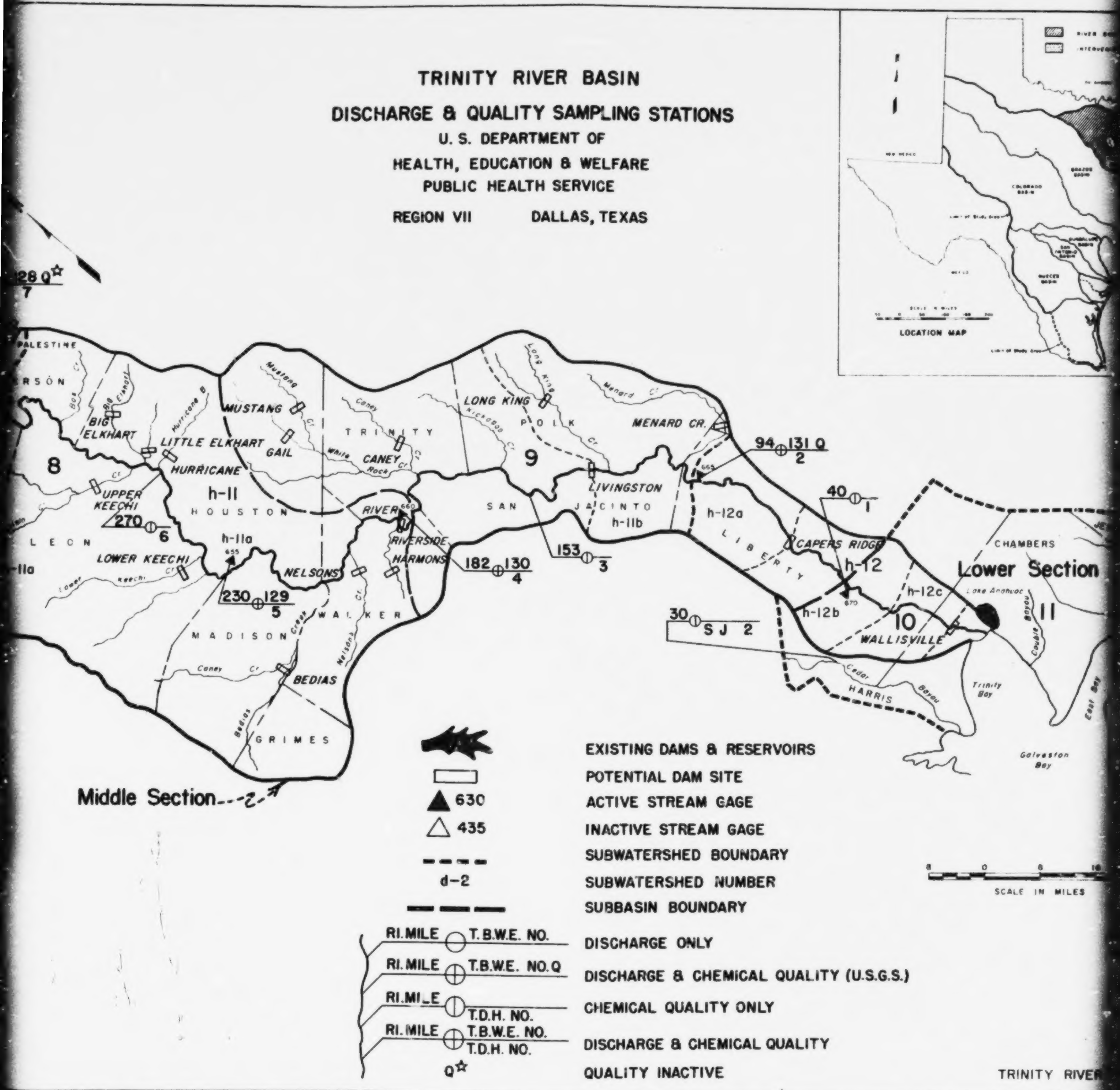
B


TR
DISCHARGE
HEALT
PU
REGION
18 109
504 24
3 25
497 23
44 120
495 22
— 110
14 121 14
451 122 Q 10
483 21
31 123 Q
475 20
393 9
375 8
313 128 Q 7
115
118
119
h-8b
Terrell
VAN ZANDT
h-8c
ROCKWALL
KAUFMAN
h-8a
HENDERSON
h-10b
7
h-8
FORNEY
Big Brushy
Kings
Cedar
Caney
Tehuacana
SCURRY Creek
CLEAR CR.
630
620
Fork
SCS-1
CATFISH CR.
Catfish
Keechi
PALESTINE
h-10c
ANDERSON
650
Box Cr.
Big Elkhart
Hurricane B
Mustang
Caney
MUSTANG Cr.
TRINITY
CEDAR CR.
TRINITY
TRINIDAD
Lake Trinidad
Cottonwood Cr.
White Rock
Cr.
625
DALLAS
5
h-10
NAVARRO
RICHLAND Cr.
PALESTINE
TENNESSEE COLONY
BIG ELKHART
LITTLE ELKHART
GAIL
White Rock
CANEY Cr.
8
HURRICANE
ELLIS
Red Oak
645
TEHUACANA
FREESTONE
h-10
Upper Keechi
UPPER KEECHI
h-11
HOUSTON
RIVER
660
BARDWELL
640
Creek
Lake Halbert
Waxahachie Cr.
EMHOUSE
h-9d
BIG ONION
Waxahachie Res.
RANKIN
h-9e
Richland
635
Tehuacana
Buffalo
LEON
270 6
h-11a
RIVERS
HARMON
h-9c
Big Onion
Chambers Cr.
h-9
PINOAK
LOWER KEECHI
Lower Keechi
655
NELSONS
h-11a
h-9b
Fork
ITAL.
6
Pinoak Cr.
17 127 12
230 129 5
WALKER
N. Fork
S. Fork
Navarro Mills Res.
LIMESTONE
632
36 125 11
MADISON
Creek
Nelsons Cr.
ALVARADO
HILL
h-9a
— 124
42 126
Caney Cr.
BEDIAS
Bedias
GRIMES
62 13
500 111
537 31
507 26
32
515 93 27
92
6 94
33
34
91 35
Q
Middle Section
RI. MIL
RI. MIL
RI. MIL
RI. MIL

C

TRINITY RIVER BASIN
DISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS


LOCATION MAP
128 Q☆
7
PALESTINE
RSON
Box Cr.
Big Elkhart
BIG ELKHART
Hurricane B.
LITTLE ELKHART
HURRICANE
8
Cr.
UPPER KEECHI
270
6
LEON
LOWER KEECHI
Lower Keechi Cr.
-11a
h-11
HOUSTON
h-11a
655
230
129
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MUSTANG
Mustang Cr.
GAIL
White Rock
Caney Cr.
CANEY
TRINITY
Cr.
RIVER
660
RIVERSIDE
HARMONS
NELSONS
WALKER
Nelsons Cr.
Creek
MADISON
Caney Cr.
BEDIAS
Bedias
GRIMES
Middle Section
SAN JACINTO
182
130
4
153
3
LONG KING
Long King
Kickapoo Cr.
POLK
Cr.
9
Menard Cr.
MENARD CR.
LIVINGSTON
h-11b
665
94
131 Q
2
h-12a
LIBERTY
40
1
CAPERS RIDGE
h-12
670
h-12b
h-12c
10
WALLISVILLE
30
SJ 2
Cedar Bayou
HARRIS
CHAMBERS
JE
Lower Section
Lake Anahuac
Double Bayou
11
Trinity Bay
East Bay
Galveston Bay
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
630 ACTIVE STREAM GAGE
435 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T. B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
8 0 8 16
SCALE IN MILES

TRINITY RIVER

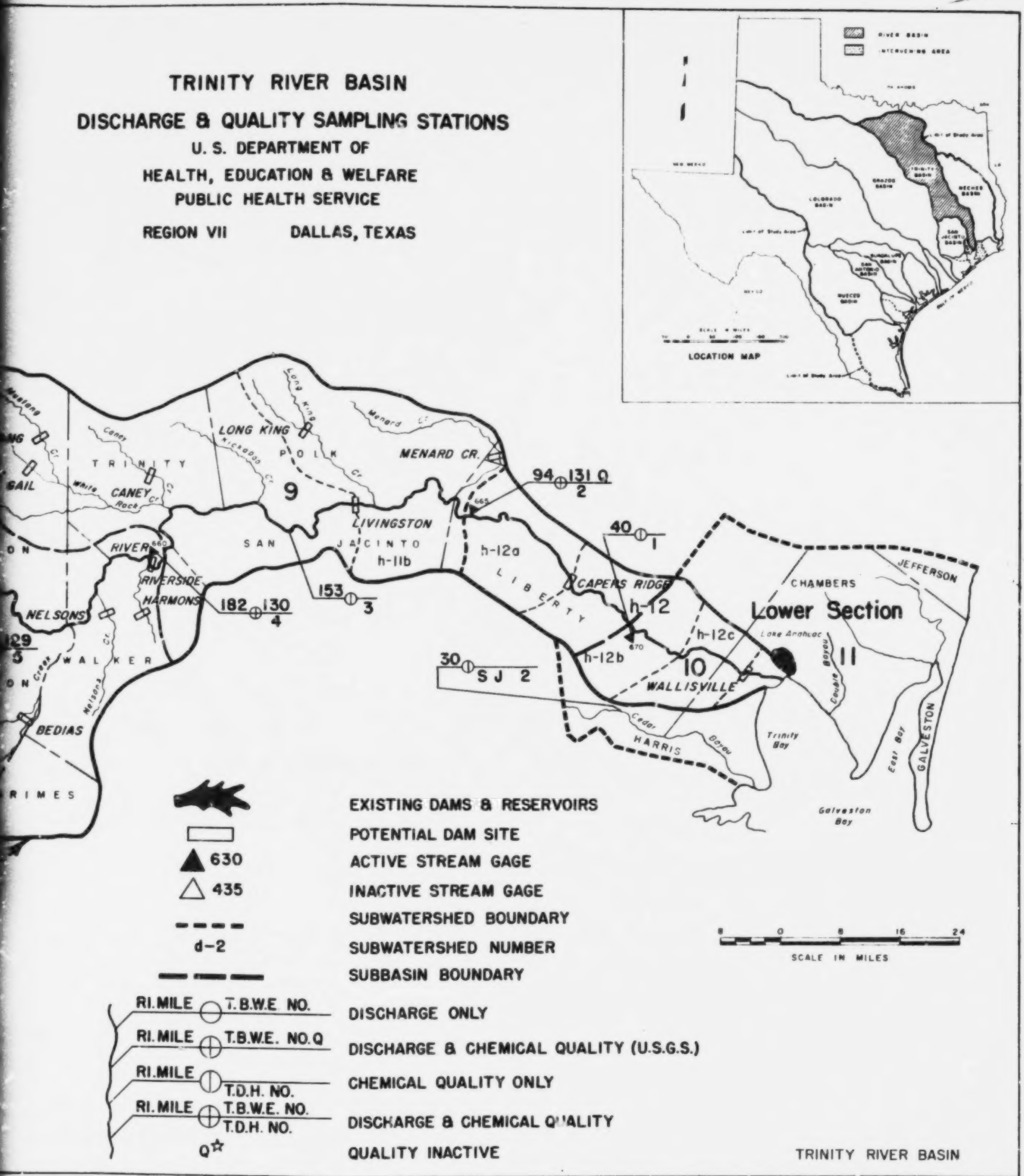
FIGURE

C

D

TRINITY RIVER BASIN
DISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS


RIVER BASIN
INTERVENING AREA
TRINITY BASIN
BRAZOS BASIN
COLORADO BASIN
NECHES BASIN
SAN JACINTO BASIN
GUADALUPE BASIN
SAN ANTONIO BASIN
NUECES BASIN
NEW MEXICO
MEXICO
Limit of Study Area
Gulf of Mexico
LOCATION MAP
Mustang Cr.
Caney Cr.
TRINITY
White Rock Cr.
CANEY
GAIL
LONG KING
Long King Cr.
Kickapoo Cr.
POLK
Menard Cr.
MENARD CR.
9
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665
LIVINGSTON
SAN JACINTO
h-11b
h-12a
LIBERTY
40
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153
3
RIVER
660
RIVERSIDE
HARMONS
182 130
4
NELSONS
129
5
WALKER
Nelsons Cr.
BEDIAS
RIMES
CAPERS RIDGE
h-12
h-12c
h-12b
670
10
WALLISVILLE
30
SJ 2
CHAMBERS
JEFFERSON
Lower Section
Lake Anahuac
11
Double Bayou
Cedar Bayou
HARRIS
Trinity Bay
East Bay
GALVESTON
Galveston Bay
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
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d-2 SUBWATERSHED NUMBER
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RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
8 0 8 16 24
SCALE IN MILES

TRINITY RIVER BASIN

FIGURE NO. T-1

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE SAN JACINTO RIVER BASIN

The San Jacinto River basin is a small basin with a total drainage area of 4,000 square miles. The river is formed at the junction of the West Fork at river mile 38 and the East Fork at river mile 40, the two main tributaries of the San Jacinto River. Buffalo Bayou, which drains the Houston area, flows into the San Jacinto at river mile 9, with the Houston Ship Channel occupying the lower 16 miles of Buffalo Bayou. The river rises at the headwaters of the West Fork, southwest of Huntsville at an elevation of about 300 feet, and flows southeastward for a total of 144 miles, emptying into Galveston Bay at Morgan's Point. The profile of the river from Lake Houston Dam to its headwaters has three distinct slopes.

River Mile	Slope
35 to 60	1.6 ft. per mile
60 to 120	2.9 ft. per mile
120 to 144	4.2 ft. per mile

The present development of the basin consists of five reservoirs with a capacity of 5,000 acre-feet or more, of which only one, Lake Houston, is used for municipal and industrial supply. The U. S. Study Commission - Texas plan for maximum development of the basin consists of four new reservoirs, each with a capacity greater than 5,000 acre-feet.

The quality analysis consists of individual studies on five reservoirs and two separate reaches, starting with Lake Creek (Dobbin) and Honea Reservoirs on the West Fork and Cleveland Reservoir on the East Fork, extending to Lake Houston on the San Jacinto. The mineral study indicates that the reservoirs will be of good quality with Humble Reservoir reaching a maximum of 330 ppm of total dissolved solids and the reach on the West Fork between Conroe and Humble Reservoir reaching 350 ppm of total dissolved solids during the critical year of 2010. The analysis included the minerals from municipal and industrial return flows, but not those of irrigation return flows. All irrigation was classed as nonproject type without return flows.

The analysis made for organic pollution shows that there is a deficiency in dissolved oxygen; but it does not go below the water quality objective of 4.0 ppm, making all water in the reaches of satisfactory quality. Augmentation will not be required in that portion of the basin above Lake Houston. Buffalo Bayou was not considered as part of this study due to tidal water affecting a portion of it and due to the excessive amounts of augmentation water required to maintain a water quality objective of 4.0 ppm of dissolved oxygen not being practical. The Bayou is a slow sluggish stream; and while it drains the Houston area, it also receives all the return flows, amounting to 701,600 acre-feet per year with a biochemical oxygen demand load of 25,540 tons, causing a septic condition throughout during all low-flow periods.

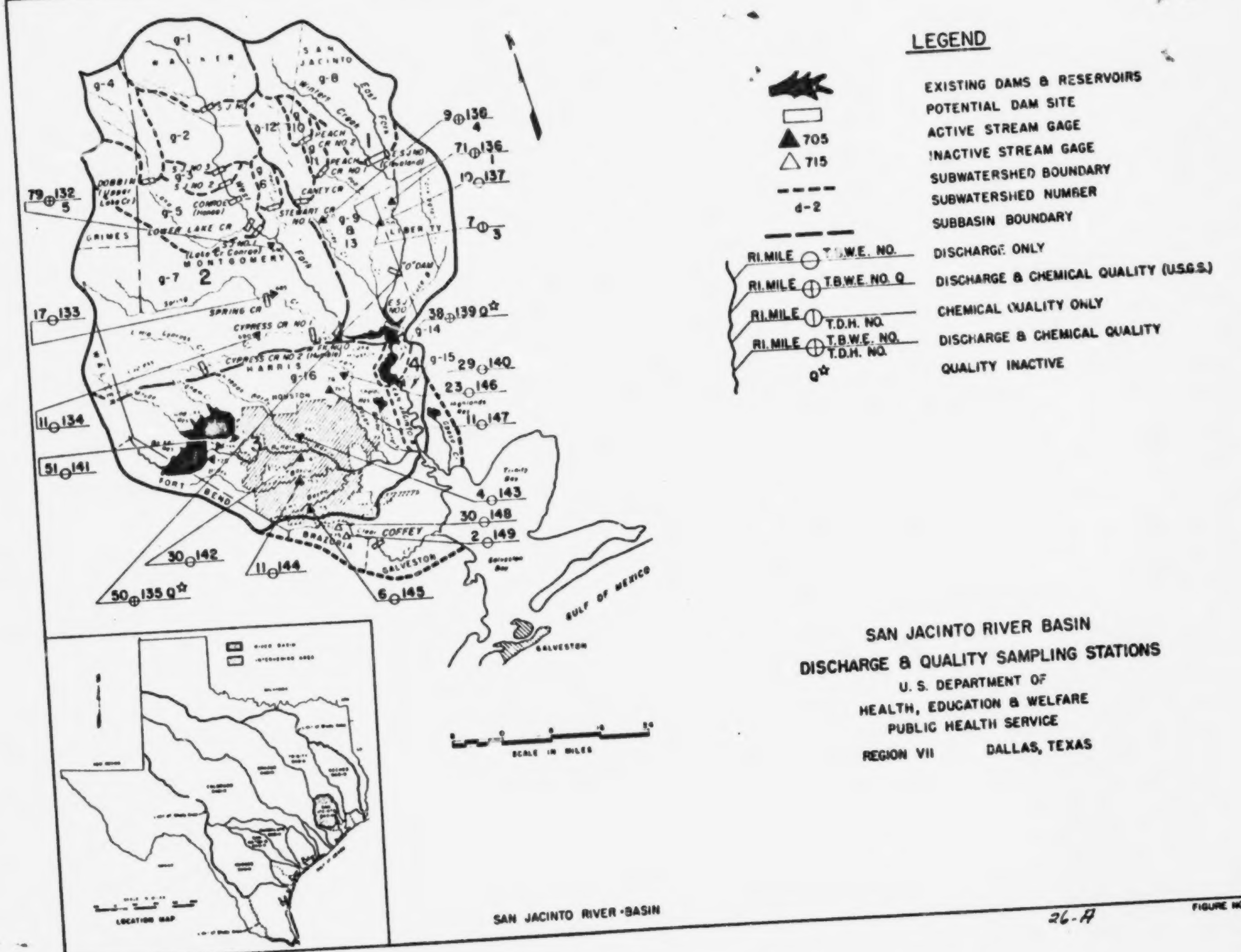
The dissolved oxygen analysis was made for the months of June, July, and August on Brays Bayou, a tributary to Buffalo Bayou. The dissolved oxygen drops to 0.0 ppm all three months and will require 5,200 acre-feet, 6,600 acre-feet, and 6,400 acre-feet of augmentation, respectively, for the three months. By augmenting Brays Bayou, the augmentation needs of Buffalo Bayou are reduced; but the three months will still require 159,500 acre-feet, 184,100 acre-feet and 184,100 acre-feet, respectively, to raise the deficiency in dissolved oxygen from 0.0 ppm to 4.0 ppm. The total requirements for the three months amount to 545,900 acre-feet.

An investigation was made on raising the degree of treatment for the removal of biochemical oxygen demand in lieu of augmentation. By increasing the treatment of the sewage from 90 percent to 97 percent and to 99 percent in some instances, the need of augmentation is eliminated.

SUMMARY SHEET
SAN JACINTO RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Headwater (ppm)	Reach (AF/yr)	Headwater (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	West Fork		Honea Reservoir	1/	124	131	--	--	--	--	--	--	--	--	TDS average for period.
		Lake Creek	Dobbin Reservoir	1/	134	157	--	--	--	--	--	--	--	--	TDS average for period.
	West Fork		M-74 to M-50	1/	--	350	--	--	5.9	--	--	--	--	--	TDS average for period.
	West Fork		Humble Reservoir	1/	247	330	--	--	--	--	--	--	--	--	TDS average for period.
	East Fork		Cleveland Reservoir	1/	132	142	--	--	--	--	--	--	--	--	TDS average for period.
	East Fork		M-30 to M-6	1/	--	230	--	--	6.4	--	--	--	--	--	TDS average for period.
San Jacinto			Lake Houston	1/	100	272	--	--	--	--	--	--	--	--	TDS average for period.

1/ The hydrologic critical year of 1956 projected for 2010 conditions.


LEGEND
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
705 ACTIVE STREAM GAGE
715 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T.B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
g-1
WALKER
SAN JACINTO
g-8
g-4
g-2
g-12
g-3
g-5
g-7
g-9
g-14
g-15
g-16
Winters Creek
East Fork
PEACH CR NO 2
PEACH CR NO 1
E S J NO 1 (Cleveland)
S J NO 3
S J NO 2
S J NO 1 (Lake Cr Conroe)
DOBBIN (Upper Lake Cr)
CONROE (Honea)
CANEY CR
STEWART CR NO 1
LOWER LAKE CR
GRIMES
MONTGOMERY
LIBERTY
O'DAM
SPRING CR
CYPRESS CR NO 1
CYPRESS CR NO 2 (Humble)
HARRIS
HOUSTON
FORT BEND
BRAZORIA
COFFEY
GALVESTON
Trinity Bay
Galveston Bay
GULF OF MEXICO
GALVESTON
1
2
8
13
14
16
79 132 5
17 133
11 134
51 141
30 142
50 135 Q☆
11 144
6 145
9 136 4
71 136 1
10 137
7 3
38 139 Q☆
29 140
23 146
11 147
4 143
30 148
2 149
SCALE IN MILES
LOCATION MAP

SAN JACINTO RIVER BASIN
DISCHARGE & QUALITY SAMPLING STATIONS
U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

SAN JACINTO RIVER BASIN

26-A

FIGURE NO SJ-1

US STUDY COMMISSION-TEXAS SJ 55

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE BRAZOS RIVER BASIN

The Brazos River basin roughly bisects the State of Texas in a northwesterly to southeasterly direction. The drainage area of the river consists of approximately 42,800 square miles in Texas and extends into the State of New Mexico for an additional 2,670 square miles. The main course of the river consists of 898 river miles to the junction of the Salt and Double Mountain Forks, with the Double Mountain Fork extending for 220 miles to its headwaters. The profile of the river has a total fall of approximately 3,100 feet, which can be broken down into four distinct grades or reaches.

River Mile	Slope
0 to 300	0.8 ft. per mile
300 to 750	1.7 ft. per mile
750 to 898	3.0 ft. per mile
0 to 220	7.6 ft. per mile.

The total of 1,118 river miles with all of its tributaries is subject to and can become polluted, having a high mineral content or a deficiency of dissolved oxygen under the projected condition for the year 2010.

At the present time the Brazos River basin has either existing or under construction more than 20 reservoirs with a capacity of 5,000 acre-feet or more. The U. S. Study Commission - Texas plan for the basin consists of 17 major new reservoirs, each with a capacity greater than 5,000 acre-feet.

The quality analysis as presented here starts with the White River Reservoir, extends throughout the basin to Brazos River mile 128 and consists of individual studies on 28 reservoirs and 34 separate reaches. The study indicates a definite need for the control of natural salts flowing into Seymour Reservoir and oil field brines flowing into Stillhouse Hollow Reservoir. The control of these sources of pollution alone will reduce the total annual augmentation needs 17 percent if water of 300 ppm total dissolved solids is used for augmentation. The mineral and dissolved oxygen analysis is based on existing runoff factors and projected return flows with their loading. All irrigation was classed as nonproject type; therefore, irrigation return flows were not considered with their high mineral load. Thus, evaporation becomes the main cause for the high buildup of minerals, requiring approximately 250,000 acre-feet per year of augmentation in reservoirs alone, using 300 ppm of total dissolved solids water. The total annual augmentation needs for the basin are as follow.

	Use of 300 ppm Water	Use of 500 ppm Water
Assuming correction of brine discharges and elimination of natural pollution	356,200 AF/yr.	611,820 AF/yr.
Assuming no correction of brine discharges and no elimination of natural pollution	429,200 AF/yr.	711,820 AF/yr.

Salt Fork

The Salt Fork of the Brazos River flows through Area 2A into the headwaters of Seymour Reservoir. During the critical year of 2010 the return flow from Area 2A, amounting to 3,100 acre-feet per year containing its biochemical oxygen demand loading of 1,020 tons, causes a deficiency in dissolved oxygen. This condition exists approximately from river mile 48 to the headwaters of Seymour Reservoir, with the dissolved oxygen dropping to a minimum of 0.1 ppm in the headwaters of the reservoir. To maintain the required water quality objective of 4.0 ppm of dissolved oxygen, an annual augmentation of 310 acre-feet per year is necessary. The month-to-month analysis of this condition is shown in Table 1-B.

Table 1-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Salt Fork

Month	Critical Point on Reach Without Augmentation For Quality: Minimum Dissolved Oxygen (ppm)	Critical Point on Reach Without Augmentation For Quality: Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	8.0	590	---
2	4.0	260	---
3	4.0	260	---
4	3.0	260	50
5	7.9	3,590	---
6	5.8	920	---
7	4.6	590	---
8	4.6	590	---
9	0.1	260	250
10	6.8	920	---
11	3.8	260	10
12	4.0	. 260	---

Total annual augmentation = 310 AF/yr.

Double Mountain Fork

The Double Mountain Fork, a tributary to the Brazos, drains Area 2B into Seymour Reservoir. This reach receives the return flow of Area 2B, amounting to 8,700 acre-feet per year containing a biochemical oxygen demand loading of 290 tons. During the critical year of 2010 a deficiency of dissolved oxygen occurs, starting at river mile 133 and continuing into the headwaters of Seymour Reservoir, with the dissolved oxygen reaching a minimum amount of 0.2 ppm in the headwaters. An annual augmentation of 2,412 acre-feet during the critical year will be required to maintain a 4.0 ppm dissolved oxygen water quality objective. Table 2-B gives the monthly breakdown for the required augmentation. The months of July and August have not been augmented due to the analysis showing the headwaters regaining to 4.0 ppm of dissolved oxygen in 0.1 mile of flow.

Table 2-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Double Mountain Fork

Month	Critical Point on Reach Without Augmentation For Quality: Minimum Dissolved Oxygen (ppm)	Critical Point on Reach Without Augmentation For Quality: Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	7.9	1,980	---
2	1.9	990	260
3	1.9	990	260
4	0.8	990	440
5	8.0	3,540	---
6	5.4	2,980	---
7	3.9	1,980	---
8	3.9	1,980	---
9	0.2	990	990
10	6.1	2,970	---
11	1.2	990	350
12	3.0	990	120

Total annual augmentation = 2,420 AF/yr.

Seymour Reservoir

Seymour Reservoir is located at river mile 896 on the Brazos River just below the junction of Salt Fork and Double Mountain Fork, tributaries of the Brazos.

In addition to the treated municipal waste return flows of Areas 2A and 2B, the reservoir receives the drainage of Dove Creek, at river mile 35 of the Salt Fork. The chemical quality of the water in Dove Creek is poor since it is high in chlorides and sulfates due to natural salt springs and salt flats in this area. This high mineral content of the water will render the water in Seymour Reservoir unsuitable for municipal, industrial, and irrigational purposes. (See Work Assignment 4.1, "Inventory of Present Water Quality," pages 3 and 21.)

Due to this high concentration of salts, two analyses of mineral content are made for Seymour Reservoir, that is with and without control for the natural salt condition in the drainage area. The mineral analyses cover the critical hydrologic period of January

1942 through the year of 1952. By the use of the existing runoff factors, allowing Seymour Reservoir to trap all minerals, the total dissolved solids will increase to 2,615 ppm prior to the critical year. This increase in minerals above the questionable limit of 800 ppm requires 700,000 acre-feet of augmentation water with a quality of 300 ppm of total dissolved solids to be placed in the reservoir prior to the critical year. This augmentation of 700,000 acre-feet will increase to 1,170,000 acre-feet if 500 ppm of total dissolved solids quality water is used. During the critical year of 2010 the mineral content of the reservoir builds up to a maximum of 4,190 ppm of total dissolved solids. If the reservoir is augmented prior to the critical year, an additional amount of augmentation can be limited to 210,000 acre-feet per year of 300 ppm water. If 500 ppm of total dissolved solids water were used for augmentation, 350,000 acre-feet per year of water would be required.

The second analysis provides for salt water control in the drainage area of Dove Creek. By removing the salts a correction can be applied to the runoff factors. This improved drainage reduces the buildup of total dissolved solids in the reservoir to 1,100 ppm prior to the critical year, and 1,860 ppm during the critical year. The augmentation necessary to reduce the total dissolved solids to the desired level prior to the critical year is 370,000 acre-feet or 615,000 acre-feet, respectively, for 300 ppm or 500 ppm augmentation water. During the critical year an additional annual amount of 160,000 acre-feet or 285,000 acre-feet for 300 or 500 ppm water, respectively, will be required. By using 500 ppm water the conservation storage is exceeded and spills downstream are required. The amounts of spills are tabulated in Table 4-B.

Seymour Reservoir is a relatively large reservoir with a reported 700,000 acre-feet of conservation storage which will be subject to a high evaporation rate. The evaporation ranges from a low of 57,500 acre-feet to a high of 174,600 acre-feet per year causing a rapid buildup of minerals.

The monthly augmentation requirements needed for the high mineral content of the reservoir are shown in Tables 3-B and 4-B. Due to the high amounts of augmentation water required without a salt water control in the drainage area, the augmentation and spills prior to the critical year for 300 ppm or 500 ppm water have not been tabulated as well as the necessary augmentation during the critical year for 500 ppm water. The amount of augmentation for the deficiency of dissolved oxygen in the Salt Fork and the Double Mountain Fork will reduce the total augmentation needed in the reservoir. This reduction amounts to 2,730 acre-feet per year.

Table 3-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Seymour Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1/] 300 ppm (AF/mo.)	Augmentation [1/] 500 ppm (AF/mo.)
1	2,656	50,000	------
2	2,719	25,000	------
3	2,830	15,000	------
4	2,906	10,000	------
5	2,915	10,000	------
6	3,205	10,000	------
7	3,279	10,000	------
8	3,548	15,000	------
9	3,746	25,000	------
10	4,007	15,000	------
11	4,100	15,000	------
12	4,190	10,000	------
TOTAL		210,000	

[1/] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 700,000 acre-feet of 300 ppm total dissolved solids water. Five hundred ppm dilution is not considered due to excessive dilution water needed but would amount to 1,170,000 acre-feet prior to the critical year. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Table 4-B

Critical Period Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Seymour Reservoir

--------------Critical Period Prior to Critical Year--------------------

Year	Maximum Mineral Concentration With Salt Water Control And Without Augmentation For Quality (ppm)	Augmentation		Spillage [1]	
		300 ppm (AF/yr)	500 ppm (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)
2000	575	-------	-------	-------	-------
2001	700	-------	-------	-------	-------
2002	825	20,000	40,000	-------	-------
2003	929	80,000	130,000	-------	-------
2004	963	50,000	80,000	-------	-------
2005	931	20,000	35,000	-------	-------
2006	1,024	80,000	130,000	-------	-------
2007	958	-------	-------	-------	20,000
2008	903	-------	-------	-------	60,000
2009	1,100	120,000	200,000	-------	75,000
TOTAL		370,000	615,000	-------	155,000

--------------------------Critical Year----------------------------

Month	Maximum Mineral Concentration With Salt Water Control And Without Augmentation For Quality (ppm)	Augmentation		Spillage [1]	
		300 ppm (AF/mo)	500 ppm (AF/mo)	300 ppm (AF/mo)	500 ppm (AF/mo)
1	1,120	-------	10,000	-------	-------
2	1,150	-------	20,000	-------	-------
3	1,200	20,000	30,000	-------	6,000
4	1,245	10,000	15,000	-------	5,000
5	1,225	20,000	30,000	-------	25,000
6	1,355	30,000	50,000	-------	25,000
7	1,429	30,000	35,000	-------	27,000
8	1,555	20,000	35,000	-------	16,000
9	1,646	10,000	20,000	-------	5,000
10	1,766	10,000	20,000	-------	5,000
11	1,812	-------	10,000	-------	-------
12	1,858	10,000	10,000	-------	-------
TOTAL		160,000	285,000	-------	114,000

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[1] Spills occur only when conservation pool is full. At the beginning of the period following that of the spill the conservation pool is full.

Millers Creek

Millers Creek, located in the approximate center of Area 2E, is the main tributary of the area for the Brazos River.

The treated municipal waste return flow from the city of Haskell is the only effluent this stream receives and amounts to 1,300 acre-feet per year, containing a biochemical oxygen demand load of 50 tons. During the critical year of 2010, the dissolved oxygen becomes deficient at approximately river mile 34 and reaches a minimum of 0.0 ppm in the headwaters of Millers Creek Reservoir. To maintain the water quality objective of 4.0 ppm of dissolved oxygen in the stream, an annual augmentation of 1,870 acre-feet will be required. Table 5-B gives the monthly requirements for the dissolved oxygen augmentation.

Table 5-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Millers Creek

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	4.0	110	---
2	4.0	110	---
3	4.0	110	---
4	3.0	210	60
5	0.0	110	240
6	0.0	110	340
7	0.0	110	340
8	0.0	110	340
9	0.0	110	240
10	0.0	110	130
11	0.0	110	130
12	0.0	110	50

Total annual augmentation = 1,870 AF/yr.

The mineral content of Millers Creek Reservoir, due primarily to evaporation during the critical year, is 813 ppm of total dissolved solids. This small amount above the questionable range of 800 ppm will be reduced to below the 800 ppm range by the dissolved oxygen augmentation of 1,870 acre-feet per year.

Lake Fort Phantom Hill

Lake Fort Phantom Hill is the main reservoir in Area 2C and is located on Elm Creek between the Clear Fork and Deadman Creek. To satisfy the water demand for Abilene the areal yield of the reservoir is increased by pumping from the Clear Fork 6,600 acre-feet per year, as well as 29,900 acre-feet per year from Seymour Reservoir and 15,800 acre-feet per year from Hubbard Creek Reservoir.

Both Hubbard Creek Reservoir and Seymour Reservoir exceed the water quality objective of 800 ppm of total dissolved solids; therefore, for the purposes of the mineral analysis it is assumed that the two reservoirs have been augmented both prior to and during the critical year and that the water is received at Lake Fort Phantom Hill Reservoir at 800 ppm of total dissolved solids.

The transfer of 45,700 acre-feet of water from the two reservoirs amounts to 69 percent of the reported net conservation storage of 66,400 acre-feet. This amount of transfer at 800 ppm along with evaporation will cause the reservoir to exceed the water quality objective of 800 ppm total dissolved solids prior to and during the critical year of 2010. The mineral content increases from 428 ppm to a maximum of 944 ppm prior to the critical year and from 655 ppm to 999 ppm during the critical year. To maintain 800 ppm at all times, 20,000 acre-feet or 34,000 acre-feet of 300 ppm or 500 ppm augmentation water will be required prior to the critical year; and during the critical year, 22,000 acre-feet or 36,500 acre-feet of 300 ppm or 500 ppm additional augmentation water per year will be required. This amount of water exceeds the conservation storage of 66,400 acre-feet and spills will occur amounting to 2,500 acre-feet or 16,500 acre-feet of 300 ppm or 500 ppm water, respectively, prior to the year 2010 and 4,000 acre-feet or 18,500 acre-feet during the critical year of 300 ppm or 500 ppm water, respectively. Table 6-B shows the yearly augmentation and spills prior to the critical year, as well as the monthly augmentation and spills for the critical year.

Table 6-B

Critical Period Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Fort Phantom Hill Reservoir

--------------Critical Period Prior to Critical Year-------------------

Year	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/yr)	Augmentation 500 ppm (AF/yr)	Spillage [1/] 300 ppm (AF/yr)	Spillage [1/] 500 ppm (AF/yr)
1996	428	-------	-------	-------	-------
1997	586	-------	-------	-------	-------
1998	604	-------	-------	-------	-------
1999	568	-------	-------	-------	-------
2000	635	-------	-------	-------	-------
2001	660	-------	-------	-------	-------
2002	755	-------	-------	-------	-------
2003	708	-------	-------	-------	-------
2004	692	-------	-------	-------	-------
2005	775	-------	-------	-------	-------
2006	944	20,000	34,000	-------	-------
2007	698	-------	-------	-------	-------
2008	790	-------	-------	-------	-------
2009	655	-------	-------	2,500	16,500
TOTAL		20,000	34,000	2,500	16,500

--------------------------Critical Year------------------------------

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo)	Augmentation 500 ppm (AF/mo)	Spillage [1/] 300 ppm (AF/mo)	Spillage [1/] 500 ppm (AF/mo)
1	685	-------	-------	-------	-------
2	710	-------	-------	-------	-------
3	738	-------	-------	-------	-------
4	764	-------	-------	-------	-------
5	730	-------	-------	2,200	2,200
6	795	-------	-------	-------	-------
7	816	-------	-------	-------	-------
8	848	4,000	6,500	-------	-------
9	925	6,000	10,000	-------	2,300
10	951	3,000	5,000	-------	3,000
11	980	3,000	5,000	-------	3,200
12	999	6,000	10,000	1,800	7,800
TOTAL		22,000	36,500	4,000	18,500

[1/] Spills occur only when conservation pool is full. At the beginning of the period following that of the spill, the conservation pool is full.

Big Sandy Creek

Big Sandy Creek is located in the lower portion of Area 2D and drains the area from Lake Cisco to Hubbard Creek Reservoir. The stream receives the return flow of 1,700 acre-feet from the city of Cisco, containing a biochemical oxygen demand load of 65 tons per year. The biochemical oxygen demand loading causes a deficiency in dissolved oxygen from river mile 25 to the headwaters of the reservoir, with the minimum dissolved oxygen of 0.0 ppm at the headwaters of the reservoir during the critical year of 2010.

A total annual augmentation of 770 acre-feet will be required to maintain a minimum dissolved oxygen of 4.0 ppm during the critical year. Table 7-B shows the monthly breakdown for the necessary augmentation.

Table 7-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Big Sandy Creek

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	9.3	840	---
2	2.4	140	30
3	0.8	140	90
4	0.0	140	130
5	6.0	640	---
6	5.4	640	---
7	0.0	140	260
8	0.0	140	180
9	2.5	240	80
10	5.3	440	---
11	8.0	840	---
12	8.9	1,040	---

Total annual augmentation = 770 AF/yr.

Hubbard Creek

Hubbard Creek is the other drainage arm for Hubbard Creek Reservoir in Area 2D. This stream carries part of the return flows, 1,400 acre-feet, from others in Area 2D and has 53 tons of biochemical oxygen demand loading per year. During the critical year of 2010, the stream becomes deficient in dissolved oxygen at approximately river mile 18 with the dissolved oxygen reaching a minimum of 0.0 ppm in the headwaters of Hubbard Creek Reservoir. To correct this deficiency and maintain the water quality objective of 4.0 dissolved oxygen, an annual augmentation of 3,040 acre-feet during the critical year will be required. Table 8-B gives the month-to-month requirements for this augmentation.

Table 8-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Hubbard Creek

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	0.0	120	90
2	0.0	120	90
3	0.0	120	170
4	0.0	120	230
5	0.0	120	330
6	0.0	120	420
7	0.0	120	420
8	0.0	120	340
9	0.0	120	340
10	0.0	120	290
11	0.0	120	180
12	0.0	120	140

Total annual augmentation = 3,040 AF/yr.

Hubbard Creek Reservoir

Hubbard Creek Reservoir, located in Area 2D, supplies municipal and industrial water to Abilene, Breckenridge, and others in Area 2D. While it receives the return flows from Cisco and others in Area 2D, the increased mineral concentration is primarily due to high evaporation. During the critical hydrologic period of 1943 through 1952, the evaporation ranges from 22,260 acre-feet to 69,580 acre-feet per year.

In the period preceding the critical year of 2010, the total dissolved solids increased from 310 ppm to 735 ppm, with an increase from 735 ppm to 2,107 ppm during the critical year.

The monthly tabulation for the necessary augmentation during the critical year to maintain 800 ppm of total dissolved solids is shown in Table 9-B and amounts to an annual total of 41,500 acre-feet or 69,500 acre-feet for 300 ppm or 500 ppm augmentation water, respectively. The dissolved oxygen augmentation in Hubbard and Big Sandy Creek will reduce the annual total needed in the reservoir by 3,810 acre-feet.

Table 9-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Hubbard Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	750	------	------
2	775	------	------
3	810	2,000	3,500
4	824	1,500	3,000
5	871	3,500	8,000
6	989	7,000	9,000
7	1,137	8,000	12,000
8	1,395	9,000	14,000
9	1,623	3,500	8,000
10	1,966	5,000	9,000
11	2,005	1,000	2,000
12	2,107	1,000	1,000
TOTAL		41,500	69,500

Lake Stamford

Lake Stamford, in the upper portion of Area 2D, is located on Paint Creek, a tributary to Clear Fork. The drainage area is small, 360 square miles, and the reservoir does not receive any return flows. Evaporation is the controlling factor for the increase in total dissolved solids during the critical hydrologic period of August 1945 through the year 1952. In the period preceding the critical year of 2010, the total dissolved solids increase from 294 ppm to 1,466 ppm. To start the critical year with 800 ppm water, it is necessary to augment the reservoir with 14,000 acre-feet or 24,000 acre-feet of 300 ppm or 500 ppm water, respectively. During the critical year, the total dissolved solids increase from 1,466 ppm to 6,590 ppm and an additional augmentation of 11,500 acre-feet or 17,500 acre-feet of 300 ppm or 500 ppm water, respectively, will be required. This added augmentation is shown on a monthly basis in Table 10-B.

Table 10-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Lake Stamford

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 1/ 300 ppm (AF/mo.)	Augmentation 1/ 500 ppm (AF/mo.)
1	1,522	500	------
2	1,606	500	1,000
3	1,718	1,000	1,500
4	1,811	1,000	1,000
5	1,955	500	1,500
6	2,360	2,000	4,000
7	2,869	1,500	3,000
8	3,822	1,500	3,000
9	4,616	1,000	1,000
10	5,870	1,500	1,000
11	6,234	500	500
12	6,590	------	------
TOTAL		11,500	17,500

1/ It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 14,000 acre-feet of 300 ppm total dissolved solids water or 24,000 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Lake Stamford

Lake Stamford, in the upper portion of Area 2D, is located on Paint Creek, a tributary to Clear Fork. The drainage area is small, 360 square miles, and the reservoir does not receive any return flows. Evaporation is the controlling factor for the increase in total dissolved solids during the critical hydrologic period of August 1945 through the year 1952. In the period preceding the critical year of 2010, the total dissolved solids increase from 294 ppm to 1,466 ppm. To start the critical year with 800 ppm water, it is necessary to augment the reservoir with 14,000 acre-feet or 24,000 acre-feet of 300 ppm or 500 ppm water, respectively. During the critical year, the total dissolved solids increase from 1,466 ppm to 6,590 ppm and an additional augmentation of 11,500 acre-feet or 17,500 acre-feet of 300 ppm or 500 ppm water, respectively, will be required. This added augmentation is shown on a monthly basis in Table 10-B.

Table 10-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Lake Stamford

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1/] 300 ppm (AF/mo.)	Augmentation [1/] 500 ppm (AF/mo.)
1	1,522	500	------
2	1,606	500	1,000
3	1,718	1,000	1,500
4	1,811	1,000	1,000
5	1,955	500	1,500
6	2,360	2,000	4,000
7	2,869	1,500	3,000
8	3,822	1,500	3,000
9	4,616	1,000	1,000
10	5,870	1,500	1,000
11	6,234	500	500
12	6,590	------	------
TOTAL		11,500	17,500

[1/] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 14,000 acre-feet of 300 ppm total dissolved solids water or 24,000 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Lake Sweetwater

Lake Sweetwater is a small reservoir supplying part of the municipal and industrial needs of the city of Sweetwater. The lake is located on Bitter Creek, a tributary to Sweetwater Creek in Area 2C. The yield of the reservoir is supplemented by a transfer of 29,300 acre-feet per year from Seymour Reservoir. For the purposes of this analysis, it is assumed that Seymour Reservoir has been augmented and all water is received at 800 ppm of total dissolved solids. The reported conservation storage of Lake Sweetwater amounts to 7,500 acre-feet per year, or about one-fourth the amount being transferred from Seymour, allowing the quality of Seymour water at 800 ppm of total dissolved solids and evaporation to control Lake Sweetwater. In the period preceding the critical year, the total dissolved solids increase from 713 ppm to a maximum of 870 ppm and during the critical year of 2010 from 830 ppm to a maximum of 892 ppm. By augmenting with water of 300 ppm of total dissolved solids, 9,000 acre-feet will be required, spilling 3,114 acre-feet downstream prior to the critical year. During the critical year, 1,600 acre-feet will be required, spilling 845 acre-feet downstream. When 500 ppm augmentation water is used, 15,000 acre-feet will be needed prior to the critical year and 2,670 acre-feet during the critical year. Spills will amount to 9,114 acre-feet and 1,573 acre-feet for the two periods, respectively.

Table 11-B shows the augmentation and spills necessary prior to the critical year and the monthly breakdown for the critical year.

Table 11-B

Critical Period Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Lake Sweetwater

-------------Critical Period Prior to Critical Year-----------------

Year	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation		Spillage 1/	
		300 ppm (AF/yr)	500 ppm (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)
2004	713	-------	-------	-------	-------
2005	786	-------	-------	-------	-------
2006	806	-------	-------	-------	-------
2007	838	3,000	5,000	610	2,610
2008	870	4,000	6,700	1,329	4,029
2009	830	2,000	3,300	1,175	2,475
TOTAL		9,000	15,000	3,114	9,114

-------------------------Critical Year---------------------------

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation		Spillage 1/	
		300 ppm (AF/mo)	500 ppm (AF/mo)	300 ppm (AF/mo)	500 ppm (AF/mo)
1	822	-------	-------	-------	-------
2	840	100	170	-------	-------
3	852	200	330	-------	68
4	830	100	170	-------	88
5	690	-------	-------	845	932
6	795	-------	-------	-------	-------
7	865	200	330	-------	-------
8	892	300	500	-------	-------
9	882	300	500	-------	141
10	850	200	330	-------	193
11	830	100	170	-------	77
12	827	100	170	-------	74
TOTAL		1,600	2,670	845	1,573

1/ Spills occur only when conservation pool is full. At the beginning of the period following that of the spill, the conservation pool is full.

Sweetwater Creek and Clear Fork

Sweetwater Creek is located in Area 2C and is a tributary of the Clear Fork. The dissolved oxygen analysis for this reach starts at mile 24 of Sweetwater Creek and runs the length of the Clear Fork from the junction of Sweetwater Creek at mile 178 on the Clear Fork to its confluence with the Brazos River at mile 760. The reach for the Clear Fork flows through Areas 2C and 2D. Other feeder streams to the Clear Fork are Deadman Creek, California Creek, Paint Creek, Hubbard Creek, Big Sandy Creek, and Gonzales Creek. During the critical year of 2010 the dissolved oxygen goes below 4.0 ppm at mile 20 on Sweetwater Creek and does not regain itself until mile 95 on the Clear Fork. The minimum dissolved oxygen is 1.0 ppm which occurs at mile 168 on the Clear Fork. To maintain the water quality objective of 4.0 ppm during the critical year, an augmentation of 4,860 acre-feet per year will be required. An examination of Lake Sweetwater shows that Bitter Creek joins Sweetwater Creek at river mile 25 and that the spills from the augmentation for excessive minerals in Lake Sweetwater could decrease the total amount of 4,860 acre-feet of augmentation needed in Sweetwater Creek. However, the month of May is the only month that spills occur when 300 ppm water is used and the spills resulting from the use of 500 ppm water are less than the month to month needs in Sweetwater Creek. Due to the varying factors of evaporation, runoff, and biochemical oxygen demand loading to the stream, spills from Lake Sweetwater are not considered as supplementing the augmentation needs of Sweetwater Creek. The month-by-month breakdown of the augmentation needs for Sweetwater Creek is listed in Table 12-B.

Table 12-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Sweetwater Creek and Clear Fork

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	4.0	1,050	-----
2	4.0	1,090	-----
3	3.1	1,090	200
4	2.3	1,090	500
5	2.4	1,090	460
6	1.6	1,090	760
7	1.6	1,090	760
8	1.0	1,090	1,120
9	1.5	1,090	770
10	2.7	1,090	290
11	4.0	1,090	-----
12	4.0	1,090	-----

Total annual augmentation = 4,860 AF/yr.

Brazos River

The analysis of this reach of the Brazos River is from river mile 795 to river mile 705, headwaters of Possum Kingdom Reservoir. Parts of Areas 2E and 2F are traversed in the 90 miles of the reach, with the Clear Fork joining the Brazos at river mile 760.

The return flows from Area 2E, amounting to 1,900 acre-feet per year containing a load of 80 tons of biochemical oxygen demand, will cause the dissolved oxygen to go below 4.0 ppm at river mile 795, reaching a minimum of 0.0 ppm at mile 783. The total depletion of oxygen or septic condition remains until the flows from Clear Fork at river mile 760 supply sufficient oxygen to bring the dissolved oxygen up to 6.0 ppm or greater, reaching the headwaters of Possum Kingdom Reservoir with a dissolved oxygen of 7.2 ppm or greater.

To correct the depletion of oxygen, an augmentation of 1,710 acre-feet per year will be necessary. Table 13-B shows the monthly augmentation required to maintain a minimum of 4.0 ppm of dissolved oxygen.

Table 13-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Brazos River

Month	Critical Point on Reach Without Augmentation For Quality: Minimum Dissolved Oxygen (ppm)	Critical Point on Reach Without Augmentation For Quality: Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	8.7	2,750	---
2	8.7	2,750	---
3	7.2	5,460	---
4	6.8	5,460	---
5	0.9	160	200
6	0.0	160	290
7	0.0	160	330
8	0.0	160	330
9	0.0	160	290
10	1.4	160	170
11	3.4	160	60
12	3.9	160	40

Total annual augmentation = 1,710 AF/yr.

Keechi Creek Reservoir

Keechi Creek Reservoir is a relatively small reservoir with a reported 33,000 acre-feet of conservation storage, yielding 6,800 acre-feet per year for Mineral Wells' municipal and industrial use. The reservoir is located in Area 2F and intercepts the drainage from 274 square miles of area. The return flows reaching Keechi Creek are not of sufficient quantity to cause a problem in a deficiency of dissolved oxygen. A high evaporation rate, ranging from 7,417 acre-feet to 11,868 acre-feet per year, causes a buildup of total dissolved solids prior to and during the critical year. In the period preceding the critical year of 2010, the total dissolved solids increase from 380 ppm to a maximum of 1,310 ppm and from 600 ppm to a maximum of 2,078 ppm during the critical year. The increase in total dissolved solids will require 6,900 acre-feet or 10,500 acre-feet of 300 ppm or 500 ppm water, respectively, prior to the critical year with an additional 5,000 acre-feet or 8,500 acre-feet per year of 300 ppm or 500 ppm water, respectively, during the critical year. The monthly augmentations are shown in Table 14-B.

Table 14-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Keechi Creek Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1/] 300 ppm (AF/mo.)	Augmentation [1/] 500 ppm (AF/mo.)
1	590	-----	-----
2	575	-----	-----
3	672	-----	-----
4	468	-----	-----
5	481	-----	-----
6	581	-----	-----
7	806	1,500	2,500
8	1,205	2,000	3,500
9	2,078	1,500	2,500
10	1,245	-----	-----
11	1,880	-----	-----
12	354	-----	-----
TOTAL		5,000	8,500

[1/] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 6,900 acre-feet of 300 ppm total dissolved solids water or 10,500 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Aquilla Reservoir

Aquilla Reservoir is located on Aquilla Creek in Area 3C. The reservoir has a reported conservation storage of 80,000 acre-feet with a total yield of 21,100 acre-feet per year. Of this yield, 20,600 acre-feet are released downstream for Area 4A. The critical hydrologic period starts in September of 1950 and extends to April of 1957, with the reservoir becoming dry at this time.

Due to evaporation, ranging from 9,675 acre-feet to 17,595 acre-feet per year, the total dissolved solids increase from 335 ppm to 650 ppm prior to the critical year, with an increase from

650 to a maximum of 1,170 ppm during the critical year of 2010. The buildup of minerals requires a total augmentation of 7,000 acre-feet or 12,000 acre-feet of 300 ppm or 500 ppm water, respectively.

Table 15-B shows the months needing augmentation to maintain the required water quality objective.

Table 15-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Aquilla Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	660	-----	-----
2	666	-----	-----
3	709	-----	-----
4	736	-----	-----
5	655	-----	-----
6	721	-----	-----
7	836	1,000	2,000
8	980	3,000	5,000
9	1,145	3,000	5,000
10	1,112	-----	-----
11	1,028	-----	-----
12	1,170	-----	-----
TOTAL		7,000	12,000

North Bosque River

North Bosque River, located in Area 3B, is part of the drainage system for Waco Reservoir and receives the return flows from Area 3B, amounting to 2,500 acre-feet containing a biochemical oxygen demand load of 140 tons. In the reach from river mile 56 to river mile 20, headwaters of Waco Reservoir, the dissolved oxygen reaches a minimum of 0.0 ppm during the critical year of 2010. This occurs in the headwaters of Waco Reservoir and will require 6,530 acre-feet per year of augmentation. Monthly augmentations are shown in Table 16-B.

Table 16-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, North Bosque River

Month	Critical Point on Reach Without Augmentation For Quality		Augmentation Required (AF/mo.)
	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	
1	0.0	340	340
2	0.0	340	390
3	0.0	340	490
4	6.6	2,350	-----
5	7.4	61,370	-----
6	0.0	340	1,060
7	0.0	340	1,100
8	0.0	340	1,130
9	0.0	340	1,100
10	0.0	340	920
11	5.4	1,340	-----
12	7.6	2,350	-----

Total annual augmentation = 6,530 AF/yr.

Lake Leon

Lake Leon, located in the headwaters of Leon River in Area 3A, has a high buildup of total dissolved solids during the critical period. Evaporation ranging from 2,120 acre-feet to 6,762 acre-feet per year, causes the total dissolved solids to increase from 240 ppm to a maximum of 670 ppm prior to the critical year. During the critical year of 2010 a total of 3,950 acre-feet or 6,500 acre-feet of 300 ppm or 500 ppm, respectively, of augmentation water will be required for an increase in total dissolved solids from 670 ppm to a maximum of 2,215 ppm. Table 17-B shows the monthly augmentation required.

Table 17-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Lake Leon

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	679	-----	-----
2	725	-----	-----
3	799	-----	-----
4	628	-----	-----
5	639	-----	-----
6	760	-----	-----
7	936	1,000	1,600
8	1,229	1,200	2,000
9	1,611	1,000	1,600
10	1,920	500	800
11	1,962	-----	-----
12	2,215	250	500
TOTAL		3,950	6,500

Stillhouse Hollow Reservoir

Stillhouse Hollow Reservoir is located in Area 3D at river mile 16 of the Lampasas River. This river is similar to the Salt Fork in that it has a high content of total dissolved solids. The high mineral content is due, however, to oil field brines, in lieu of natural salt springs. Two analyses were made of the reservoir, the first being without control or correction to the stream. Under this condition, the total dissolved solids increased from 976 ppm to 1,087 ppm prior to the critical year of 2010 and from 1,087 to 1,246 ppm during the critical year.

In the period preceding the year 2010, an augmentation of 20,000 acre-feet or 35,000 acre-feet for 300 ppm or 500 ppm water, respectively, will be required. During the year 2010, an added amount of 23,000 acre-feet or 35,000 acre-feet of 300 ppm or 500 ppm water will be needed to maintain the mineral water quality objective.

By controlling the stream and applying a corrected runoff factor, the reservoir does not have a buildup of minerals above the water quality objective of 800 ppm, and augmentation will not be required. Monthly calculations for augmentation without stream control are shown in Table 18-B.

Table 18-B

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Stillhouse Hollow Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)[1]	Augmentation [2] 300 ppm (AF/mo.)	Augmentation [2] 500 ppm (AF/mo.)
1	1,082	-----	-----
2	1,081	-----	-----
3	1,123	2,000	1,000
4	1,176	-----	2,000
5	985	5,000	8,000
6	1,024	4,000	8,000
7	1,093	2,000	2,000
8	1,142	4,000	4,000
9	1,226	2,000	4,000
10	1,246	-----	2,000
11	1,078	4,000	2,000
12	1,037	-----	2,000
TOTAL		23,000	35,000

[1] Without stream control for oil field brines.

[2] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 20,000 acre-feet of 300 ppm total dissolved solids water or 35,000 acre-feet of 500 ppm total dissolved water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Brazos River at Waco Return

The Brazos River below Waco at approximately river mile 402, Area 3G, receives from the city of Waco its municipal treated waste effluent amounting to 102,800 acre-feet per year containing a mineral load of 29,280 tons. During the critical year, the Brazos River will have a flow at Waco of 81,000 acre-feet which will be released from the Possum Kingdom - Whitney Reservoir system. This flow is already high in total dissolved solids (805 ppm) and with the added load from the city of Waco which includes the load of 29,280 tons and source load at 710 ppm, the total dissolved solids in the river increase to 884 ppm. Annual augmentation amounting to 20,000 acre-feet or 50,000 acre-feet will be needed for 300 ppm or 500 ppm water, respectively. Monthly augmentations are considered to be constant through the year, since upstream releases are controlled and a monthly breakdown has not been computed.

Further downstream the total dissolved solids are again increased to 890 ppm due to Marlin's return flow at approximately river mile 368 and Bryan's return flow at approximately river mile 284; however, Bryan's return flow is somewhat augmented by the "good" water from Little River. The augmentation flows provided at Waco will supply sufficient water to maintain the river within the water quality objective of 800 ppm of total dissolved solids.

Somerville Reservoir

Somerville Reservoir, located on Yegua Creek in Area 3F, receives the return flows from Rockdale and part of others in Area 3F. The high mineral load of Rockdale's treated municipal waste, combined with evaporation, will cause the total dissolved solids in the reservoir to increase from 470 ppm to 1,385 ppm prior to the critical year and will require an augmentation of 150,000 acre-feet or 265,000 acre-feet, respectively, of 300 ppm or 500 ppm water. The high amount of augmentation will cause the reported conservation storage of 143,900 acre-feet to be exceeded and spills will occur amounting to 94,000 acre-feet or 160,000 acre-feet, respectively, for the two types of water.

During the critical year of 2010, the total dissolved solids increase from 1,385 ppm to a maximum of 2,603 ppm. The added increase of minerals will require augmentation amounting to 60,000 acre-feet or 100,000 acre-feet of 300 ppm or 500 ppm water, respectively. The conservation storage is again exceeded and spills will occur, amounting to 22,000 acre-feet or 65,000 acre-feet. Table 19-B shows yearly augmentation required prior to the critical year and monthly augmentation for the critical year.

Table 19-B

Critical Period Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Somerville Reservoir

-------------Critical Period Prior to Critical Year-----------------

Year	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation		Spillage 1/	
		300 ppm (AF/yr)	500 ppm (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)
2004	469	-------	-------	-------	-------
2005	784	-------	-------	-------	-------
2006	925	30,000	50,000	-------	-------
2007	719	-------	-------	29,580	50,000
2008	1,121	60,000	130,000	-------	60,000
2009	1,385	60,000	85,000	64,420	50,000
TOTAL		150,000	265,000	94,000	160,000

-------------------------Critical Year---------------------------

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation		Spillage 1/	
		300 ppm (AF/mo)	500 ppm (AF/mo)	300 ppm (AF/mo)	500 ppm (AF/mo)
1	1,415	-------	-------	-------	-------
2	1,194	-------	-------	5,000	5,000
3	1,247	5,000	10,000	-------	10,000
4	1,211	-------	-------	-------	-------
5	1,270	5,000	10,000	1,000	10,000
6	1,421	15,000	20,000	7,000	10,000
7	1,660	10,000	10,000	5,000	-------
8	1,921	5,000	20,000	-------	15,000
9	2,239	10,000	15,000	-------	10,000
10	2,448	5,000	5,000	1,000	-------
11	2,603	5,000	10,000	1,000	5,000
12	2,255	-------	-------	2,000	-------
TOTAL		60,000	100,000	22,000	65,000

1/ Spills occur only when conservation pool is full. At the beginning of the period following that of the spill, the conservation pool is full.

Navasota River

The Navasota River drains all of Area 3H and has one existing reservoir, Bistone, in the upper portion, and two proposed reservoirs, Wayland Crossing at river mile 143 and Millican Reservoir at river mile 24. The reach between these two proposed reservoirs will receive the return flows from Mexia and others in Area 3H, causing the dissolved oxygen to drop to a minimum of 1.5 ppm in the reach and to a minimum of 0.0 ppm in the headwaters of Millican Reservoir. To bring the stream up to the water quality objective of 4.0 ppm, an augmentation of 8,330 ppm during the critical year of 2010 will be required. It will be noted in Tables 20-B and 21-B that the headwaters of the reservoir control for the maximum augmentation of 8,330 acre-feet; however, it is necessary to augment the stream with an additional 350 acre-feet during the two months of April and May, making the total augmentation 8,680 acre-feet.

Table 20-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Navasota River

Month	Critical Point on Reach Without Augmentation For Quality		Augmentation Required (AF/mo.)
	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	
1	4.1	1,170	---
2	4.1	1,170	---
3	4.0	1,170	---
4	3.7	1,170	130
5	3.2	1,170	220
6	3.1	1,170	300
7	1.6	1,180	530
8	1.5	1,180	530
9	1.5	1,180	530
10	2.3	1,180	220
11	3.8	1,170	---
12	4.1	1,170	20

Total annual augmentation = 2,480 AF/yr.

Table 21-B

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Headwaters Millican Reservoir

	Critical Point on Reach Without Augmentation For Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	7.1	2,780	-----
2	9.8	16,780	-----
3	5.9	2,780	-----
4	5.1	2,780	-----
5	7.6	21,080	-----
6	2.3	1,980	890
7	0.0	1,180	1,770
8	0.0	1,180	1,840
9	0.0	1,180	1,840
10	0.0	1,180	1,420
11	5.5	2,780	-----
12	1.5	1,180	570

Total annual augmentation = 8,330 AF/yr.

Brazos River

The Brazos River at approximately river mile 232 will have an increase to 840 ppm total dissolved solids due to the city of Navasota's return flows. During the critical year of 2010, the augmentation provided at Waco and releases from Somerville Reservoir will in turn reduce the total dissolved solids at Navasota return flow to within the limits of the established water quality objective.

From this point to river mile 128 at Allens Creek, the quality of the river will remain good, with the total dissolved solids becoming 800 ppm. The flow in the river at this point, reported to be 500,000 acre-feet during the critical year, will be of sufficient amount that with no additional return flows to be received by the river, the quality of the river will remain within the required water quality objective for the last 128 miles.

SUMMARY SHEET
BRAZOS RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	Salt Fork	White River	White River Res.	1/	489	638	--	--	--	--	--	--	--	--	TDS average for period.
	Salt Fork		M-48 to M-0	1/	--	--	--	--	0.7	0.1	--	310	310	310	M-0 = M-898 Brazos River, also headwaters Seymour Reservoir.
	Double Mt. Fork		M-133 to M-0	1/	--	--	--	--	1.1	0.2	--	2,420	2,420	2,420	M-0 = M-898 Brazos River, also headwater Seymour Reservoir.
Brazos			Seymour Reservoir M-896	1/	2,615	4,190	210,000 2/	350,000 3/	--	--	--	--	207,270 9/	347,270 9/	Added 700,000 AF of 300 ppm prior to crit. yr.
Brazos			Seymour Reservoir M-896	1/	1,100	1,860	160,000	285,000 4/	--	--	--	--	157,270 9/	282,270 9/	With salt water control. Added 370,000 AF of 300 ppm prior to critical year or added 615,000 AF of 500 ppm prior to critical year.
	Millers Creek		M-34 to M-9	5/	-- 5/	--	--	--	1.0	0.0	--	1,870	1,870	1,870	Headwaters Millers Cr. Reservoir.
			Millers Cr. Res. M-9	6/	781	813	--	--	--	--	--	--	--	--	TDS are average for period.
	Clear Fork	Elm Creek Clear Creek	Lake Abilene) Lake Kirby)	5/	412	390	--	--	--	--	--	--	--	--	TDS are average for period. Lakes treated as one.
	Clear Fork	Elm Creek	Lake Ft. Phantom Hill	5/	655	999	22,000 7/	36,500 8/	--	--	--	--	22,000	36,500	Added 20,000 AF of 300 ppm prior to crit. yr. or added 34,000 AF of 500 ppm prior to crit. yr.
	Gonzales Cr.	Hubbard Cr. Big Sandy Cr.	Lake Cisco	5/	444	659	--	--	--	--	--	--	--	--	TDS are average for period.

1/ The hydrologic critical year of 1952 projected for 2010 conditions.
2/ Spills not computed.
3/ Spills not computed
4/ Spill 155,000 acre-feet of 500 ppm prior to critical year and 114,000 acre-feet during critical year.
5/ The hydrologic critical year of 1956 projected for 2010 conditions.
6/ The hydrologic critical year of 1945 projected for 2010 conditions.
7/ Spill 2,500 acre-feet of 300 ppm prior to critical year and 4,000 acre-feet during critical year.
8/ Spill 16,500 acre-feet of 500 ppm prior to critical year and 18,500 acre-feet during critical year.

9/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

SUMMARY SHEET (Continued)
BRAZOS RIVER BASIN

					Minerals				Dissolved Oxygen						
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed		Total Augmentation (DO &/or Minerals)		
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	Gonzales Cr.	Hubbard Cr. Big Sandy Cr.	M-25 to M-0	1/	--	--	--	--	2.5	0.0	--	770	770	770	Headwaters Hubbard Creek Reservoir.
	Gonzales Cr.	Hubbard Cr.	M-18 to M-7	1/	--	--	--	--	2.1	0.0	--	3,040	3,040	3,040	Headwaters Hubbard Creek Reservoir.
			Hubbard Cr. Res. M-7	1/	735	2,107	41,500	69,500	--	--	--	--	37,690 6/	65,690 6/	Mineral augmentation reduced by amount of DO augmentation.
	Clear Fork	California Cr. Paint Cr.	Lake Stamford	1/	1,466	6,590	11,500	17,500	--	--	--	--	11,500	17,500	Added 14,000 AF of 300 ppm prior to crit. yr. or added 24,000 AF of 500 ppm prior to crit. yr.
	Clear Fork	California Cr.	M-36 to M-0	2/	--	--	--	--	1.6	--	--	--	--	--	Tributary augmentation not considered. M-0 = M-728 Clear Fork.
	Clear Fork	Deadman Creek	M-12 to M-0	2/	--	--	--	--	3.3	--	--	--	--	--	Tributary augmentation not considered. M-0 = M-133 Clear Fork.
	Clear Fork	Gonzales Cr.	M-12 to M-0	2/	--	--	--	--	2.3	--	--	--	--	--	Tributary augmentation not considered. M-0 = M-24 Clear Fork.
	Clear Fork	Sweetwater Cr. Bitter Cr.	Lake Sweetwater	3/	830	892	1,600 4/	2,670 5/	--	--	--	--	1,600	2,670	Added 9,000 AF of 300 ppm prior to critical year or added 15,000 AF of 500 ppm prior to critical year.
	Clear Fork	Sweetwater Cr.	M-24 to M-0	2/	--	--	--	--	1.2	--	--	--	--	--	M-0 = M-178 Clear Fork.
	Clear Fork		M-178 to M-0	2/	--	--	--	--	1.0	--	4,860	--	4,860	4,860	M-0 = M-760 Brazos. Augmentation made at Sweetwater return.

1/ The hydrologic critical year of 1952 projected for 2010 conditions.
2/ The hydrologic critical year of 1956 projected for 2010 conditions.
3/ The hydrologic critical year of 1954 projected for 2010 conditions.
4/ Spill 3,114 acre-feet of 300 ppm prior to critical year and 845 acre-feet during the critical year.
5/ Spill 9,114 acre-feet of 500 ppm prior to critical year and 1,575 acre-feet during the critical year.

6/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

SUMMARY SHEET (Continued)
BRAZOS RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Headwater (ppm)	Reach (AF/yr)	Headwater (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	Salt Creek	Flint Creek	Salt Cr. Reservoir) Lake Eddleman)	1/	412	390	--	--	--	--	--	--	--	--	TDS are average for period.
Brazos			M-795 to M-705	2/	--	--	--	--	0.0	6.0	1,710	--	1,710	1,710	Headwaters Possum Kingdom Reservoir.
Brazos			Possum Kingdom Res. M-687.5	2/	640	880	--	--	--	--	--	--	--	--	The augmentation flow from upstream & spills from Lake Ft. Phantom Hill & Sweetwater Res. will control the TDS.
	Keechi Creek		Keechi Cr. Res.	2/	600	2,078	5,000	8,500	--	--	--	--	5,000	8,500	Added 6,900 AF of 300 ppm prior to critical year or added 10,500 AF of 500 ppm prior to critical year.
Brazos			M-654 to M-472	2/	--	--	--	--	7.1	--	--	--	--	--	Headwaters Whitney Res.
Brazos			Whitney Res., M-442	2/	684	816	--	--	--	--	--	--	--	--	TDS are average for period
	Aquilla Cr.		Aquilla Reservoir	2/	660	1,170	7,000	12,000	--	--	--	--	7,000	12,000	
Brazos			M-417 at Aquilla Cr.	2/	--	810	--	--	7.3	--	--	--	--	--	TDS are average for period
	N. Bosque R.		M-56 to M-20	2/	--	--	--	--	1.9	0.0	--	6,530	6,530	6,530	Headwaters Waco Res. Augmentation made in reach.
	N. Bosque R.		Waco Res., M-5	2/	521	600	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	Leon River	Lake Leon	1/	672	2,215	3,950	6,500	--	--	--	--	3,950	6,500	
	Little River	Leon River	Proctor Res., M-239	1/	342	678	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	Leon River	Belton Res., M-155	2/	575	641	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	Lampasas River	Stillhouse Hollow Reservoir, M-16	2/	1,087	1,246	23,000	35,000	--	--	--	--	23,000	35,000	Without correction to stream. Added 20,000 AF of 300 ppm prior to critical year or added 35,000 AF of 500 ppm prior to critical year.

1/ The hydrologic critical year of 1954 projected for 2010 conditions.
2/ The hydrologic critical year of 1956 projected for 2010 conditions.

SUMMARY SHEET (Continued)
BRAZOS RIVER BASIN

					Minerals				Dissolved Oxygen						
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed		Total Augmentation (DO &/or Minerals)		
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
	Little River	Lampasas River	Stillhouse Hollow Res., M-16	1/	553	634	--	--	--	--	--	--	--	--	With correction to stream.
	Little River		At Lampasas River	1/	--	920	--	--	--	--	--	--	--	--	TDS are average for period. Correction to Lampasas R. will reduce TDS.
	Little River		At Knob Creek, Temple Return, M-82	1/	--	890	--	--	--	--	--	--	--	--	TDS are average for period. Correction to Lampasas R. will reduce TDS.
	Little River	San Gabriel R. N. San Gabriel	N. San Gabriel Res.	1/	441	491	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	San Gabriel R. S. San Gabriel	S. San Gabriel Res.	1/	463	540	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	San Gabriel R.	Laneport Res.	1/	518	616	--	--	--	--	--	--	--	--	TDS are average for period.
	Little River	San Gabriel R. Brushy Cr.	M-24 to M-0	1/	--	--	--	--	0.0	--	--	--	--	--	M-0 = M-55 on Gabriel R. Augmentation not considered.
	Little River		At San Gabriel R.	1/	--	806	--	--	6.2	--	--	--	--	--	TDS are average for period.
	Little River	Elm Creek	M-24 to M-0 Elm Creek	1/	--	--	--	--	0.0	--	--	--	--	--	Augmentation not considered.
	Little River		At Elm Cr., M-27 5	1/	--	727	--	--	6.2	--	--	--	--	--	TDS are average for period.
Brazos			At Waco, M-403	1/	--	805	--	--	--	--	--	--	--	--	TDS are average for period.
Brazos			At Waco Return M-402	1/	--	884	20,000	50,000	5.2	--	--	--	20,000	50,000	TDS are average for period. DO at M-331 = 7.4 ppm.
Brazos			Marlin Return, M-368	1/	--	890	--	--	--	--	--	--	--	--	TDS are average for period.
Brazos			Above Little River M-317	1/	--	815	--	--	--	--	--	--	--	--	TDS are average for period.
Brazos			At Little R., M-315.8	1/	--	780	--	--	6.4	--	--	--	--	--	TDS are average for period.
Brazos			At Bryan Return	1/	--	815	--	--	--	--	--	--	--	--	TDS are average for period.

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

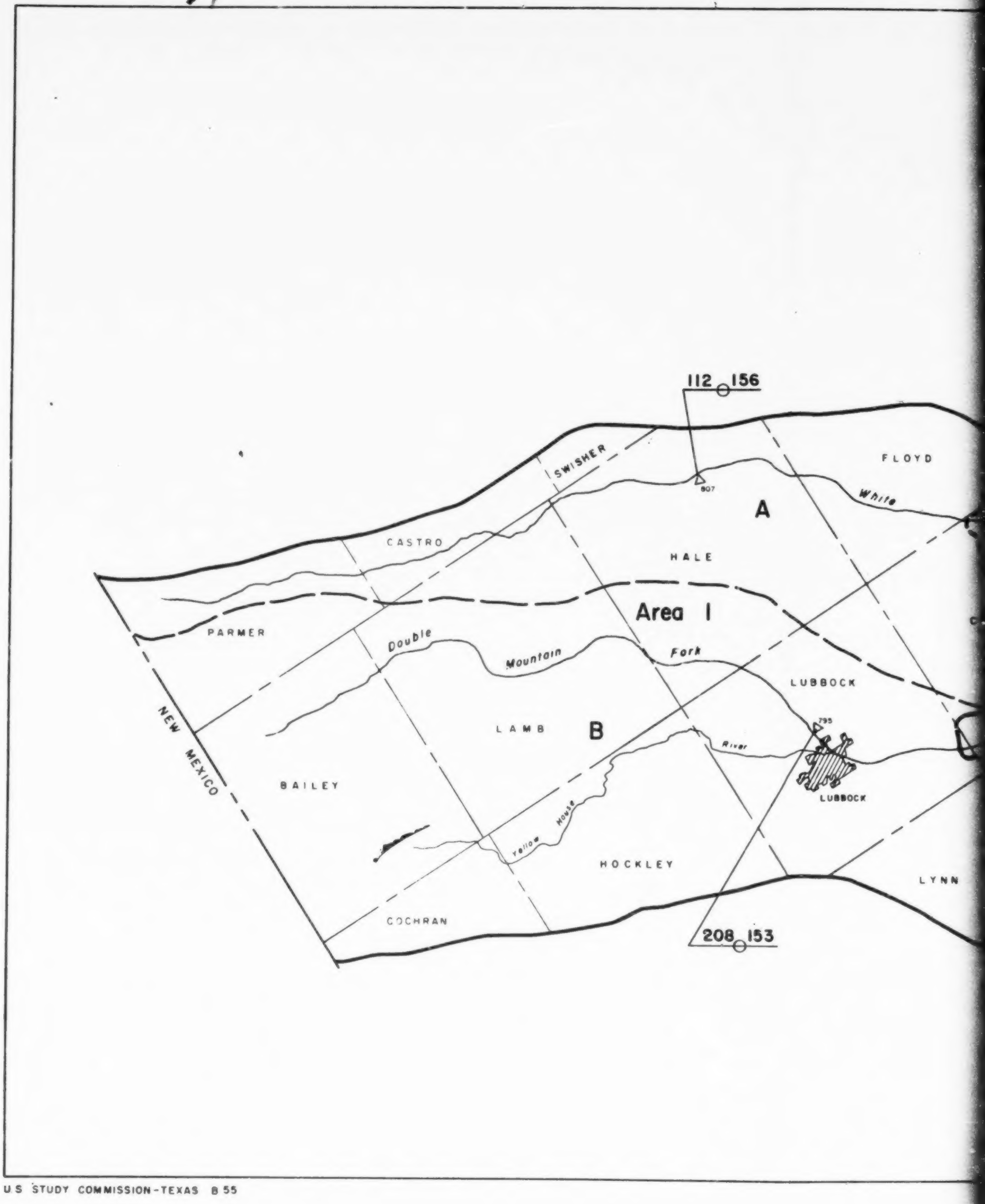
SUMMARY SHEET (Continued)
BRAZOS RIVER BASIN

River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Minerals: Crit. Year Conc. Start (ppm)	Minerals: Crit. Year Conc. During (ppm)	Minerals: Augmentation Needed 300 ppm (AF/yr)	Minerals: Augmentation Needed 500 ppm (AF/yr)	Dissolved Oxygen: Min. Conc. Reach (ppm)	Dissolved Oxygen: Min. Conc. Headwater (ppm)	Dissolved Oxygen: Augmentation Needed Reach (AF/yr)	Dissolved Oxygen: Augmentation Needed Headwater (AF/yr)	Total Augmentation (DO &/or Minerals) 300 ppm (AF/yr)	Total Augmentation (DO &/or Minerals) 500 ppm (AF/yr)	Remarks
	Yegua Cr.	East Yegua Cr.	M-68 to M-20	1/	--	--	--	--	4.0	--	--	--	--	--	Headwaters Somerville Res.
	Yegua Cr.		Somerville Res.	1/	1,385	2,603	60,000[2]	100,000[3]	--	--	--	--	60,000	100,000	Added 150,000 AF of 300 ppm prior to critical year or added 265,000 AF of 500 ppm prior to critical year.
	Yegua Creek		M-20 to M-0	1/	--	--	--	--	6.2	--	--	--	--	--	M-0 = M-247 Brazos River.
Brazos			At Yegua Cr.,M-247	1/	--	1,010	--	--	--	--	--	--	--	--	TDS average for period.
Brazos			At Yegua Cr.,M-247	1/	--	838	--	--	--	--	--	--	--	--	TDS reduced from 1,010 ppm to 800 ppm or better by augmented releases upstream & spills from Somerville Reservoir.
	Navasota R.		Bistone Reservoir	4/	651	480	--	--	--	--	--	--	--	--	TDS average for period. Reservoir empty at start of critical year.
	Navasota R.		Wayland Reservoir	4/	595	529	--	--	--	--	--	--	--	--	TDS average for period.
	Navasota R.		M-105 to M-24	1/	--	--	--	--	1.5	0.0	2,480	8,330	8,680[5]	8,680[5]	Headwaters Millican Res. See Tables 20-B & 21-B.
	Navasota R.		Millican Res.,M-24	1/	504	733	--	--	--	--	--	--	--	--	TDS average for period.
	Navasota R.		M-24 to M-0	1/	--	--	--	--	7.2	--	--	--	--	--	
Brazos			Below Navasota R. & Navasota Return	1/	--	840	--	--	--	--	--	--	--	--	TDS average for period.
Brazos			At Allen Cr.,M-128	1/	--	800	--	--	--	--	--	--	--	--	TDS average for period.

	300 ppm	500 ppm
Augmentation for Maintenance of Dissolved Oxygen Quality:	30,190	30,190
Augmentation for Maintenance of Mineral Quality Without Salt Control:	399,010	681,630
Total:	429,200	711,820
Augmentation for Maintenance of Dissolved Oxygen Quality:	30,190	30,190
Augmentation for Maintenance of Mineral Quality With Salt Control:	326,010	581,630
Total:	356,200	611,820

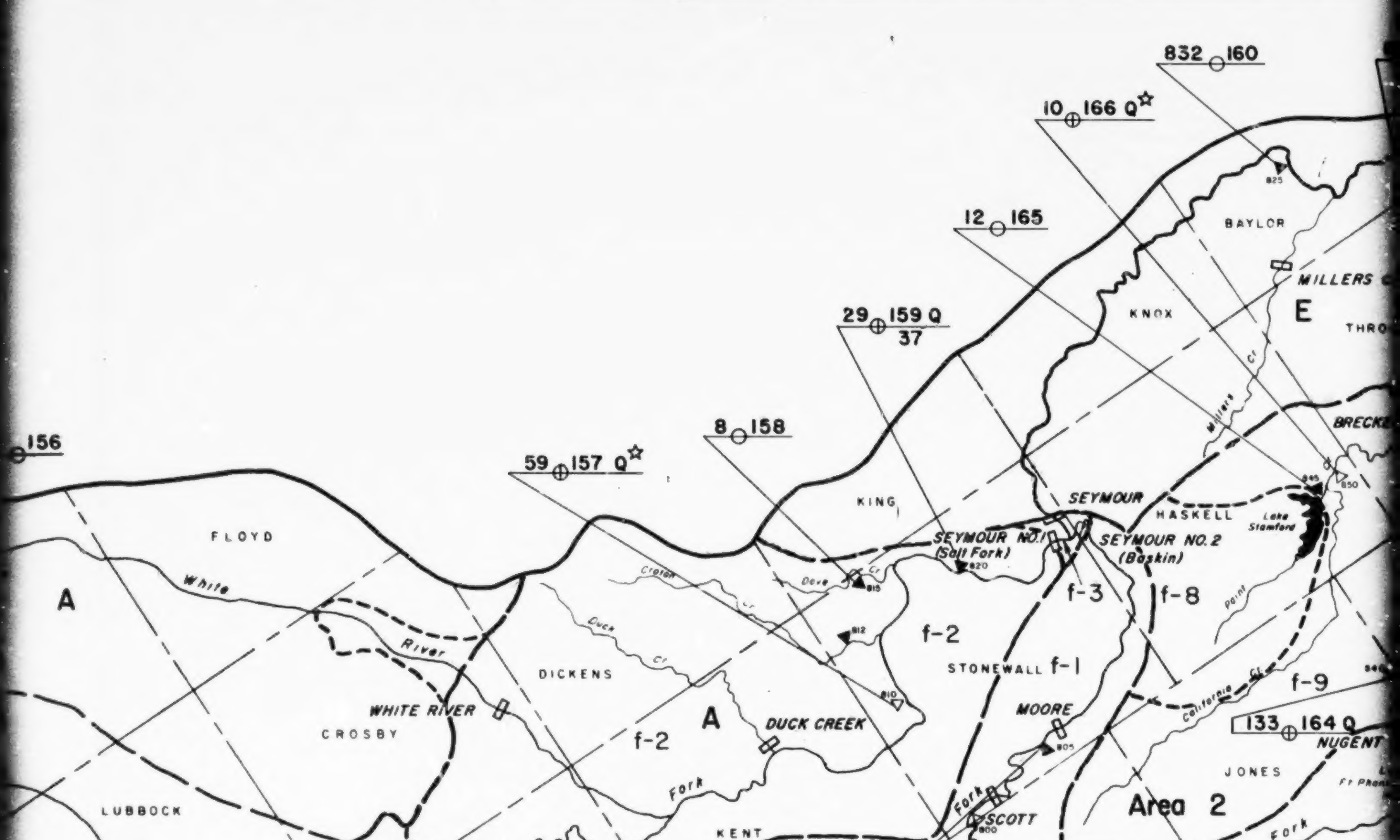
1/ The hydrologic critical year of 1956 projected for 2010 conditions.
2/ Spill 94,000 AF of 300 ppm prior to critical year and 22,000 AF during the critical year.
3/ Spill 160,000 AF of 500 ppm prior to critical year and 65,000 AF during the critical year.
4/ The hydrologic critical year of 1952 projected for 2010 conditions.
5/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.

A

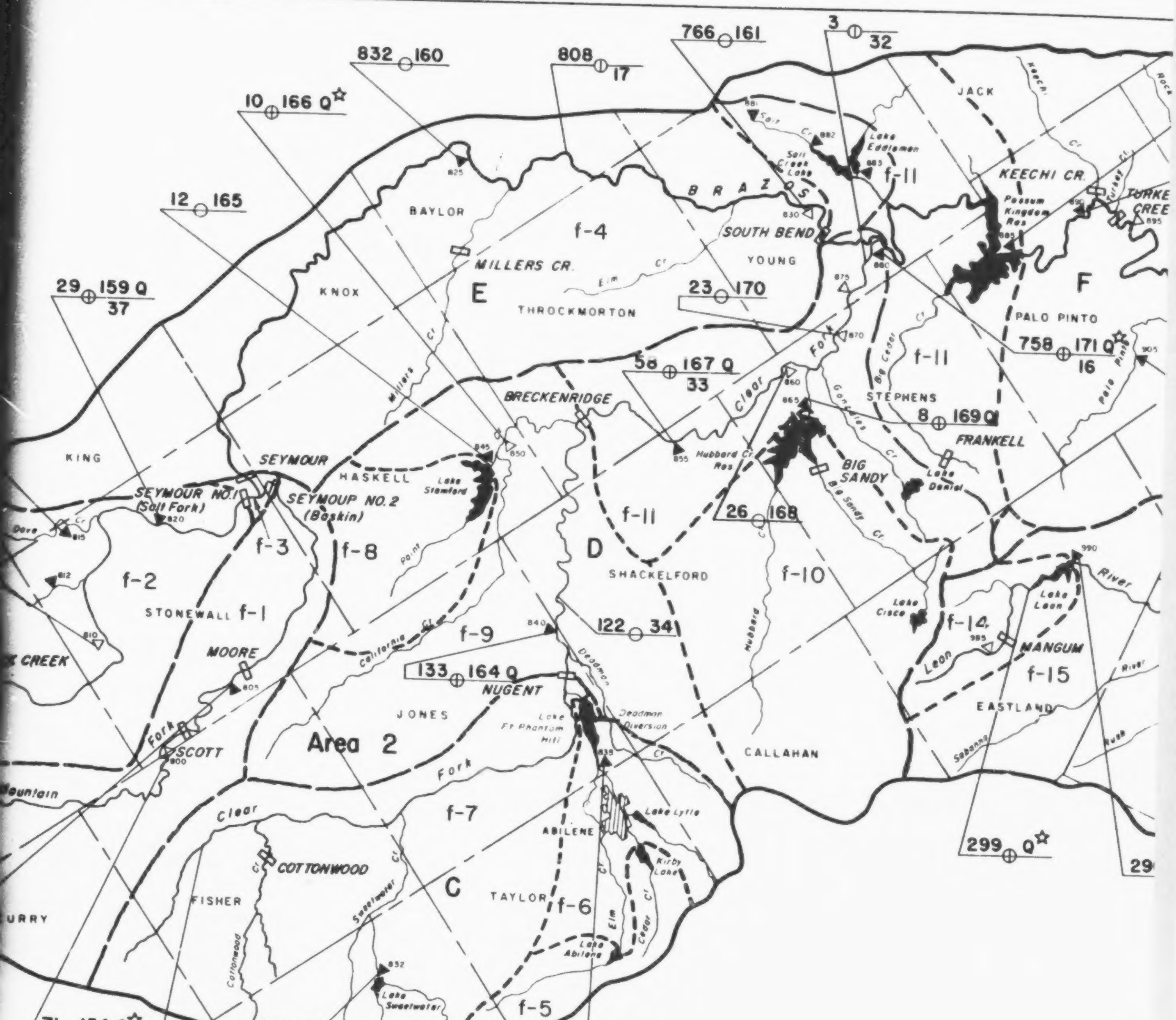


112 156
SWISHER
807
FLOYD
White
A
CASTRO
HALE
Area 1
PARMER
Double Mountain Fork
LUBBOCK
NEW MEXICO
LAMB
B
795
River
BAILEY
LUBBOCK
Yellow House
HOCKLEY
LYNN
COCHRAN
208 153

B

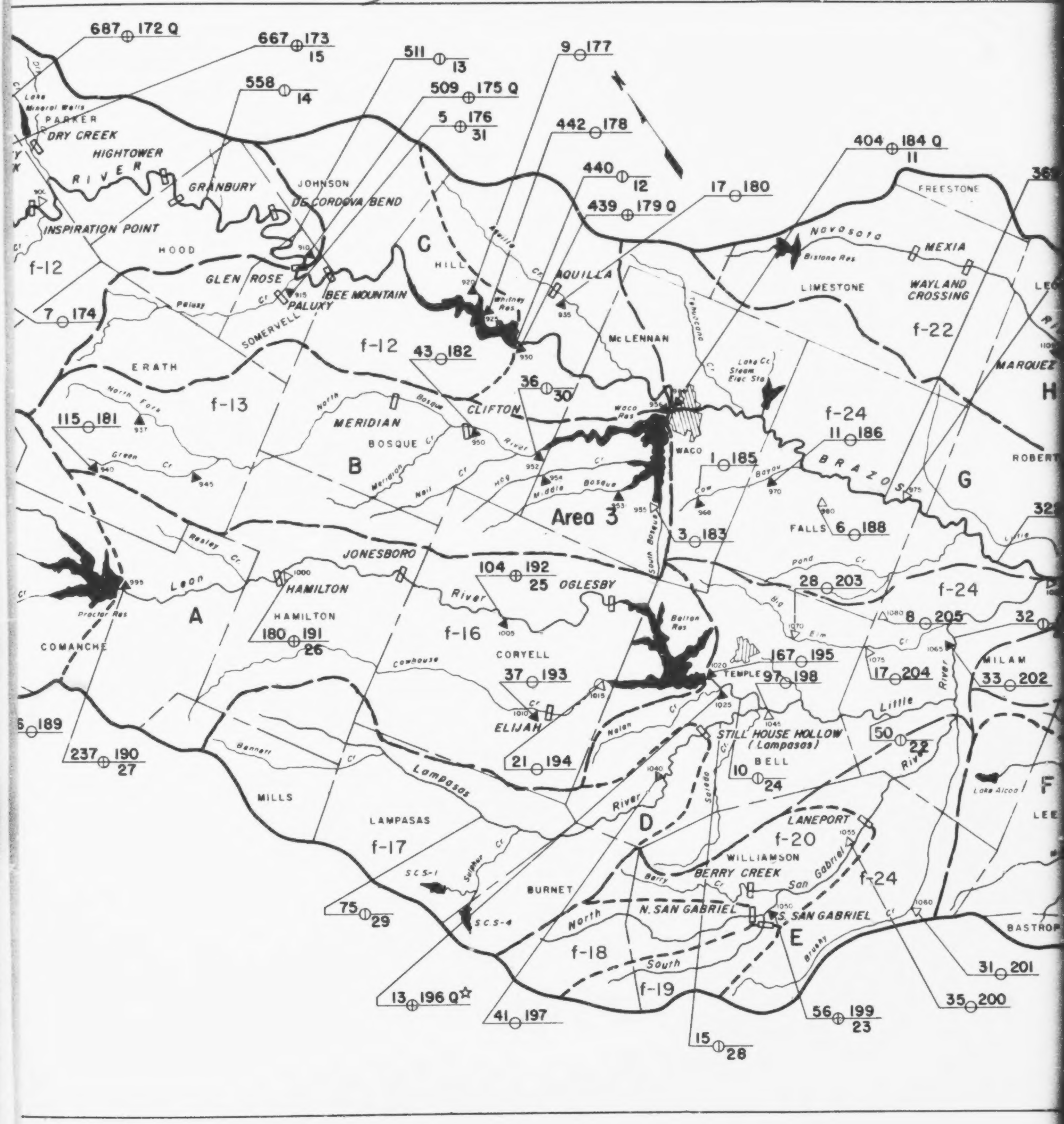

832 160
10 166 Q☆
12 165
29 159 Q
37
8 158
59 157 Q☆
156
133 164 Q
208 153
35 155 Q
36
71 154 Q☆
213 35
9 162
825
BAYLOR
MILLERS C
KNOX
E
THRO
BRECKE
Millers Cr
KING
SEYMOUR
HASKELL
SEYMOUR NO.1
(Salt Fork)
SEYMOUR NO. 2
(Baskin)
820
815
812
810
845
850
Lake Stamford
f-3
f-8
f-2
f-1
f-9
Paint
Croton
Dove Cr
Duck Cr
STONEWALL
California Cr
FLOYD
A
White
River
DICKENS
WHITE RIVER
CROSBY
A
f-2
DUCK CREEK
MOORE
805
NUGENT
JONES
Ft Phant
Area 2
LUBBOCK
Fork
KENT
Fork
SCOTT
800
Salt
795
River
Double
Mountain
Fork
f-7
Clear
COTTONWOOD
LUBBOCK
B
f-1
C
TAYLO
GARZA
FISHER
SCURRY
Sweetwater Cr
832
Cottonwood
LYNN
Lake Sweetwater
NOLAN
f-

C

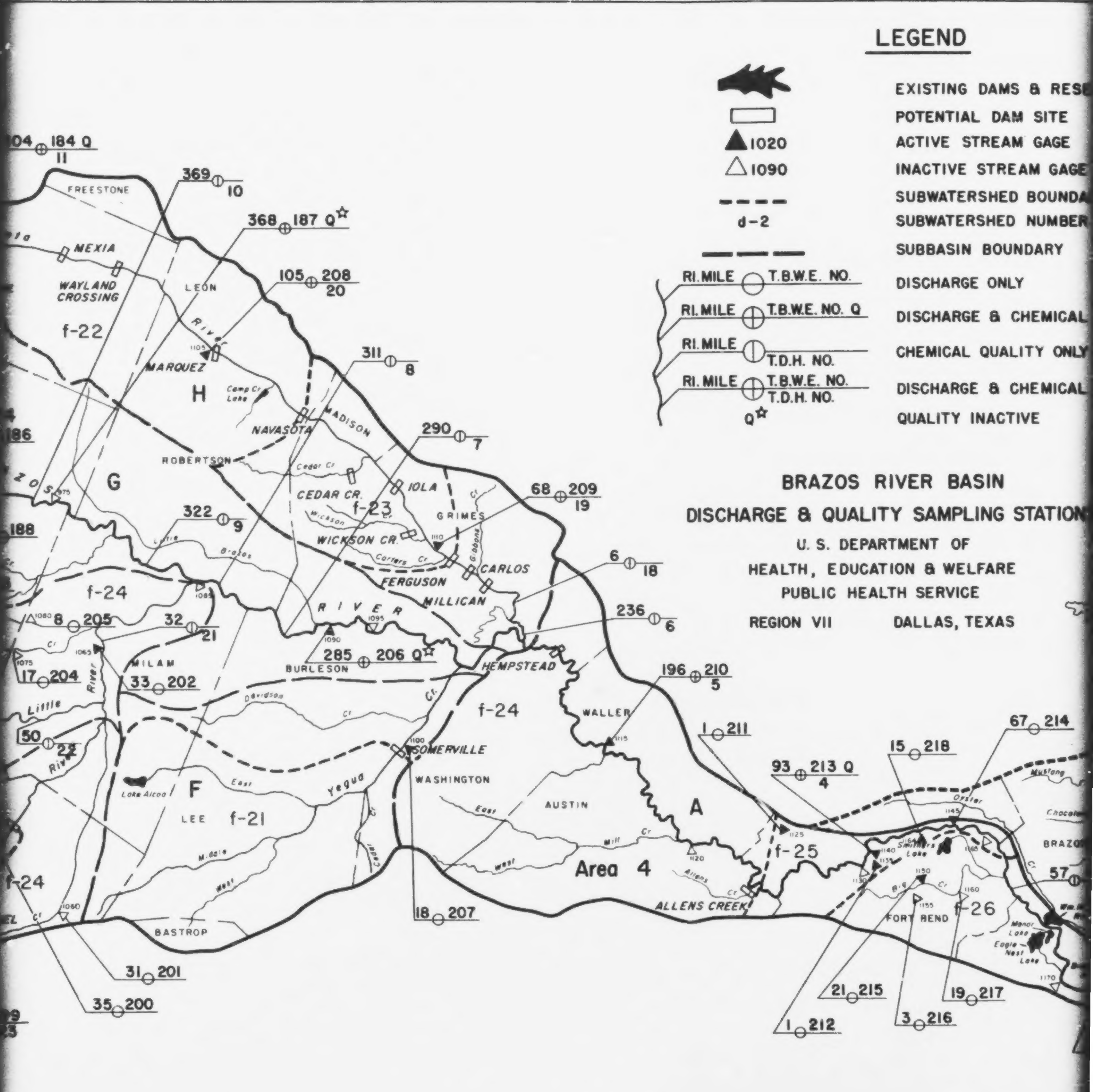


766 161
3 32
832 160
808 17
10 166 Q☆
12 165
29 159 Q 37
23 170
58 167 Q 33
758 171 Q☆ 16
8 169 Q
26 168
122 34
133 164 Q
71 154 Q☆
213 35
9 162
4 163
299 Q☆
29
JACK
Keechi
Rock
Lake Eddleman
Salt Creek Lake
Salt Cr
f-11
KEECHI CR.
Possum Kingdom Res
TURKEY CREEK
BRAZOS
SOUTH BEND
YOUNG
BAYLOR
f-4
MILLERS CR.
Elm Cr
KNOX
E
THROCKMORTON
F
PALO PINTO
Palo Pinto
Clear Fork
Big Cedar Cr
Gonzales Cr
STEPHENS
FRANKELL
BRECKENRIDGE
Millers Cr
Hubbard Cr Res
BIG SANDY
Big Sandy Cr
Lake Daniel
KING
SEYMOUR
SEYMOUR NO.1 (Salt Fork)
SEYMOUR NO.2 (Baskin)
HASKELL
Lake Stamford
f-11
D
f-3
f-8
f-2
STONEWALL
f-1
Paint Cr
SHACKELFORD
f-10
Hubbard Cr
Lake Cisco
Lake Leon
River
f-14
Leon
MANGUM
f-15
EASTLAND
Sabanna
Rush
CREEK
Dove Cr
MOORE
California Cr
f-9
Deadman
NUGENT
JONES
Lake Ft Phantom Hill
Deadman Diversion
CALLAHAN
Area 2
SCOTT
Fork
Mountain
Clear Fork
f-7
Lake Lytle
ABILENE
Kirby Lake
COTTONWOOD
Cottonwood Cr
FISHER
URRY
Sweetwater Cr
C
TAYLOR
f-6
Elm Cr
Cedar Cr
Lake Abilene
Lake Sweetwater
NOLAN
f-5

D


687 172 Q
667 173 15
511 13
558 14
509 175 Q
5 176 31
9 177
442 178
440 12
439 179 Q
17 180
404 184 Q 11
Lake Mineral Wells
PARKER
DRY CREEK
HIGHTOWER
RIVER
GRANBURY
JOHNSON
DE CORDOVA BEND
INSPIRATION POINT
HOOD
f-12
GLEN ROSE
PALUXY
BEE MOUNTAIN
Paluxy Cr
SOMERVELL
7 174
C
HILL
Aquilla Cr
AQUILLA
Whitney Res
McLENNAN
Tehuacana Cr
Navasota
Bistone Res
FREESTONE
MEXIA
LIMESTONE
WAYLAND CROSSING
f-22
MARQUEZ
H
ERATH
f-13
North Fork
115 181
Green Cr
f-12
43 182
North Bosque
MERIDIAN
CLIFTON
BOSQUE
36 30
Waco Res
Lake Cr Steam Elec Sta
WACO
f-24
11 186
1 185
Cow Bayou
BRAZOS
G
ROBERTSON
B
Meridian Cr
Neils Cr
Hog Cr
Middle Bosque
Area 3
3 183
FALLS
6 188
South Bosque
Resley Cr
JONESBORO
104 192 25
OGLESBY
Pond Cr
28 203
f-24
Leon
Proctor Res
A
HAMILTON
HAMILTON
180 191 26
River
f-16
Belton Res
Big Elm Cr
8 205
32
COMANCHE
CORYELL
Cowhouse
167 195
TEMPLE
97 198
17 204
MILAM
33 202
37 193
ELIJAH
Nolan Cr
STILL HOUSE HOLLOW (Lampasas)
Little River
50 22
6 189
237 190 27
Bennett Cr
21 194
10 24
BELL
Lake Alcoa
F
LEE
MILLS
Lampasas
River
D
Salado Cr
LANEPORT
f-20
LAMPASAS
f-17
WILLIAMSON
San Gabriel
f-24
BERRY CREEK
Berry Cr
SCS-1
Sulphur Cr
SCS-4
BURNET
75 29
N. SAN GABRIEL
S. SAN GABRIEL
North
E
f-18
South
Brushy
f-19
BASTROP
31 201
35 200
13 196 Q☆
41 197
56 199 23
15 28

E


LEGEND
EXISTING DAMS & RESE
POTENTIAL DAM SITE
1020 ACTIVE STREAM GAGE
1090 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDA
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T.B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL
Q☆ QUALITY INACTIVE
104 184 Q 11
369 10
368 187 Q☆
105 208 20
311 8
290 7
68 209 19
322 9
6 18
236 6
32 21
8 205
17 204
33 202
50 22
285 206 Q☆
196 210 5
1 211
93 213 Q 4
15 218
67 214
57
18 207
31 201
35 200
21 215
1 212
3 216
19 217
186
188
FREESTONE
MEXIA
WAYLAND CROSSING
LEON
River
MARQUEZ
Camp Cr Lake
H
NAVASOTA
MADISON
f-22
G
ROBERTSON
Cedar Cr
CEDAR CR.
IOLA
f-23
GRIMES
Wickson Cr
WICKSON CR.
Carters Cr
Gibbons Cr
CARLOS
FERGUSON
MILLICAN
BRAZOS
Little Brazos
f-24
RIVER
BURLESON
MILAM
HEMPSTEAD
WALLER
Davidson Cr
Little River
f-24
SOMERVILLE
WASHINGTON
Lake Alcoa
F
LEE
f-21
East
Yegua
Middle
West
Cedar Cr
AUSTIN
East Mill Cr
West
A
Area 4
Allens Cr
ALLENS CREEK
f-25
Oyster
Mustang
Chocolate
BRAZOS
Smithers Lake
Big Cr
FORT BEND
f-26
Manor Lake
Eagle Nest Lake
BASTROP
f-24
1075
1080
1065
1085
1090
1095
1100
1105
1110
1115
1120
1125
1130
1135
1140
1145
1150
1155
1160
1165
1170
975

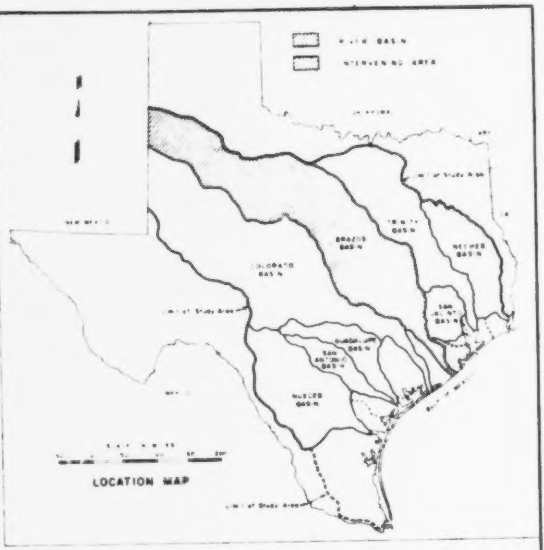
BRAZOS RIVER BASIN
DISCHARGE & QUALITY SAMPLING STATION

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

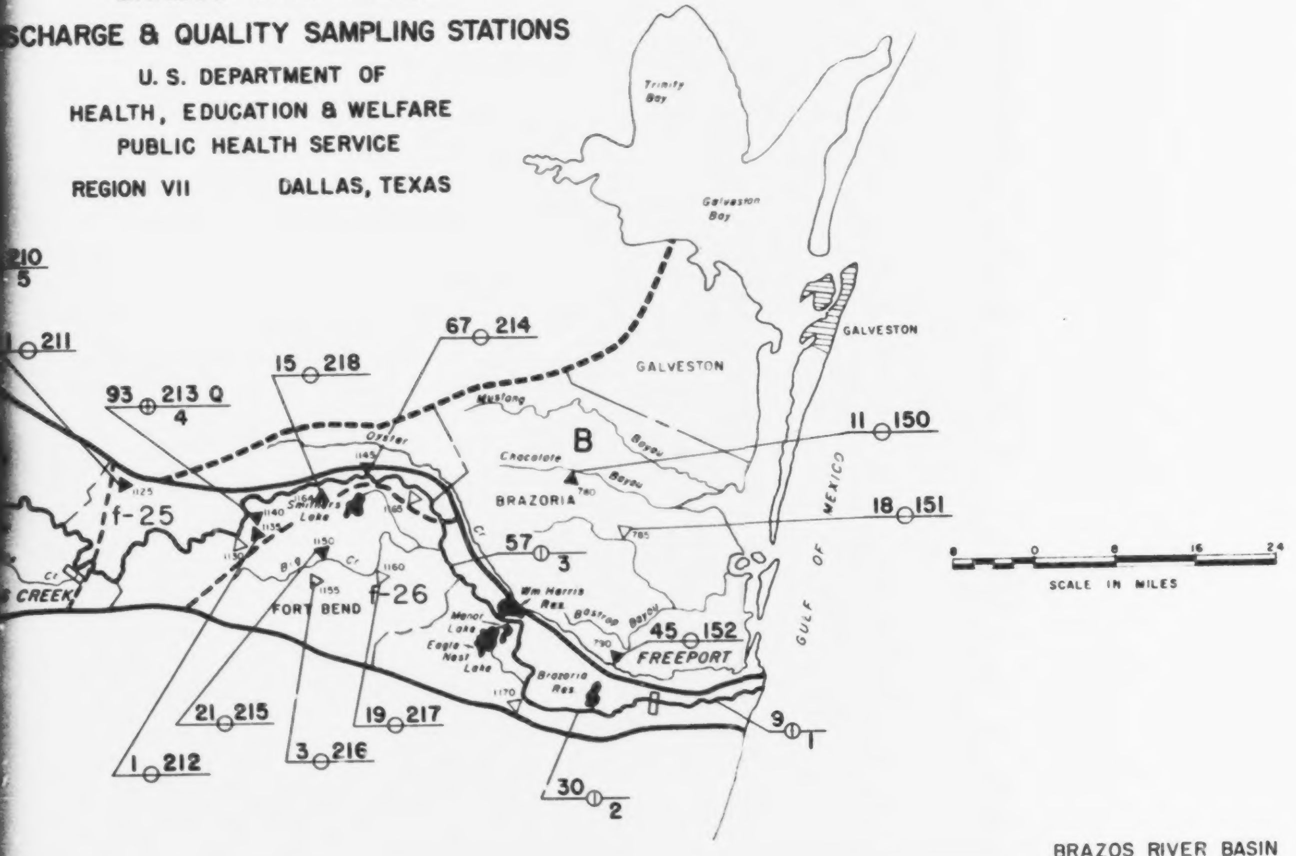
F

LEGEND

◆	EXISTING DAMS & RESERVOIRS
▭	POTENTIAL DAM SITE
▲1020	ACTIVE STREAM GAGE
△1090	INACTIVE STREAM GAGE
- - - -	SUBWATERSHED BOUNDARY
d-2	SUBWATERSHED NUMBER
— — —	SUBBASIN BOUNDARY
LE ⊖ T.B.W.E. NO.	DISCHARGE ONLY
ILE ⊕ T.B.W.E. NO. Q	DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
ILE ⦶ T.D.H. NO.	CHEMICAL QUALITY ONLY
ILE ⊕ T.B.W.E. NO. T.D.H. NO.	DISCHARGE & CHEMICAL QUALITY
Q☆	QUALITY INACTIVE


RIVER BASIN
INTERVENING AREA
OKLAHOMA
NEW MEXICO
Limit of Study Area
COLORADO BASIN
BRAZOS BASIN
TRINITY BASIN
NECHES BASIN
SAN JACINTO BASIN
GUADALUPE BASIN
SAN ANTONIO BASIN
NUECES BASIN
MEXICO
GULF OF MEXICO
SCALE IN MILES
LOCATION MAP

BRAZOS RIVER BASIN
SCHARGE & QUALITY SAMPLING STATIONS
U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS


210
5
1 211
93 213 Q
4
15 218
67 214
Trinity Bay
Galveston Bay
GALVESTON
GALVESTON
Mustang
Bayou
Oyster
Chocolate
Bayou
B
BRAZORIA
780
785
11 150
18 151
GULF OF MEXICO
1125
f-25
1145
1140
1135
1164
Smithers Lake
1165
1130
1150
B-9
Cr
Cr
1160
1155
FORT BEND
f-26
S CREEK
Cr
57 3
Wm Harris Res.
Bastrop Bayou
Manor Lake
Eagle Nest Lake
790
45 152
FREEPORT
Brazoria Res.
1170
21 215
19 217
1 212
3 216
9 1
30 2
0 8 16 24
SCALE IN MILES

BRAZOS RIVER BASIN

FIGURE NO. B-1

52 A

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE COLORADO RIVER BASIN

The Colorado River rises on the High Plains of New Mexico and flows in a south-southeasterly direction across the geographical center of Texas. The basin has a drainage area of approximately 39,900 square miles in the state of Texas, with a maximum width of 170 miles being in the upper and central parts and narrowing in the last 100 miles of the 890 miles of river course to 10 - 15 miles.

The main stem of the river has a total fall of approximately 2,760 feet, with five breaks in the slope.

River Mile	Slope
0 to 298	1.44 ft. per mile
298 to 446	3.98 ft. per mile
446 to 570	2.18 ft. per mile
570 to 790	3.68 ft. per mile
790 to 890	7.60 ft. per mile

Present development of the Colorado River basin has 14 reservoirs with capacities of 5,000 acre-feet or more. Six of these comprise the Lower Colorado River Authority's system of reservoirs and are located from river mile 298 to river mile 446. The U. S. Study Commission - Texas plan for future development of the basin calls for the addition of 14 new reservoirs, with 5 of these located in the adjoining area of the Lavaca - Navidad River basin.

The quality analysis for excessive minerals and for a deficiency of dissolved oxygen consists of individual studies on 26 reservoirs and 3 separate reaches. The study indicates a need of correcting the natural salt and oil field brines reaching the river between Lake J. B. Thomas and Robert Lee Reservoir to enable reducing the augmentation needs of Robert Lee Reservoir to a reasonable amount.

The analysis shows that the total dissolved solids in the Ganado Reservoir will exceed the water quality objective of 800 ppm of total dissolved solids; however, augmentation has not been considered since the yields of the reservoirs in the Lavaca - Navidad basin are to be used for interbasin diversions through the proposed coastal canal. An analysis of the quality of water in the canal is not possible until the sources of its supply are determined.

The total augmentation needs of the Colorado basin amount to 56,200 acre-feet when water of 300 ppm of total dissolved solids is used or 86,200 acre-feet when 500 ppm water is used. Of this total amount only 4,200 acre-feet is needed for the deficiency of dissolved oxygen.

Robert Lee Reservoir

Robert Lee Reservoir is located in Area 2B on the Colorado River and intercepts drainage below Lake J. B. Thomas. The area includes Areas 1B, 2A, and 2B, with a total return flow of 296,800 acre-feet per year. The data furnished for operations of the stream and reservoirs assign 171,500 acre-feet of return flows to be reused locally, leaving 125,300 acre-feet to be returned to the streams. Area 1B, lying west of the Cap Rock Escarpment is considered as noncontributing; therefore, the 101,300 acre-feet from this area is lost to evaporation and percolation. The operation data provided do not account for the remaining 24,000 acre-feet of return flows and assume it to be also noncontributing. With this assumption, organic pollution will not occur in the reach of the Colorado River from Lake J. B. Thomas to Robert Lee Reservoir. This matter should be re-evaluated prior to the construction of the Robert Lee Reservoir.

An examination of the drainage area shows two sources of mineral pollution. In the area immediately below Lake J. B. Thomas at Bull Creek, the river contains a high salt content from oil field brines. The area drained by Beals Creek contains several salt springs and salt flats. Due to this high concentration of salts, two mineral analyses have been made for the reservoir, one without correction for the salts, which shows the possible buildup of the total dissolved solids, and the other the analysis with correction for the salts.

The reservoir has a proposed conservation storage of 300,000 acre-feet and with no return flows the buildup of total dissolved solids is due to evaporation. The evaporation ranges from 31,000 acre-feet to 53,000 acre-feet during the critical period. In the period preceding the critical year of 2010 the total dissolved solids increase from 1,470 ppm to 2,745 ppm. By correcting the flow of salts in the drainage area, the increase in total dissolved solids for the same period will be from 370 ppm to 690 ppm. In comparing the increase in total dissolved solids for the critical year, the increase without salt correction will be from 2,745 ppm to 4,580 ppm and with correction for salts the increase will be from 690 ppm to 1,150 ppm.

To maintain a water quality objective of 800 ppm of total dissolved solids for the critical year, an augmentation of 28,000 acre-feet or 43,000 acre-feet will be required for 300 ppm or 500 ppm water, respectively, after corrections for the salt conditions have been made to the drainage area. Table 1-C shows the monthly increase in total dissolved solids and the amounts of augmentation required.

Table 1-C

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Robert Lee Reservoir

Month	Maximum [1] Mineral Concentration Without Salt Correction (ppm)	Maximum [1] Mineral Concentration With Salt Correction (ppm)	Augmentation [2] 300 ppm (AF/mo.)	Augmentation [2] 500 ppm (AF/mo.)
1	2,800	700	-----	-----
2	2,854	716	-----	-----
3	2,964	741	-----	-----
4	3,060	765	-----	-----
5	3,236	809	-----	-----
6	3,460	865	8,000	12,000
7	3,720	930	6,000	10,000
8	4,156	1,039	8,000	12,000
9	4,156	1,039	-----	1,000
10	4,400	1,100	4,000	6,000
11	4,400	1,100	-----	-----
12	4,580	1,150	2,000	2,000
TOTAL			28,000	43,000

[1] Without augmentation for quality.

[2] Augmentation is for maximum mineral concentration assuming salt correction.

Twin Buttes Reservoir

Twin Buttes Reservoir is located in Area 2C on both the Middle Concho and South Concho Rivers. The streams do not receive any return flows, eliminating the question of organic pollution. The reservoir has a conservation storage of 160,000 acre-feet, with its yield supplying part of the needs of San Angelo. Evaporation ranging from 22,000 acre-feet to 32,000 acre-feet causes an increase in total dissolved solids during the critical period. In the period preceding the critical year of 2010, the minerals increase from 395 ppm to 775 ppm and during the critical year from 775 ppm to 1,175 ppm. This increase of total dissolved solids above the water quality objective of 800 ppm requires an augmentation of 14,000 acre-feet or 23,000 acre-feet of 300 ppm or 500 ppm water, respectively. Table 2-C shows the augmentation requirements on a monthly basis.

Table 2-C

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Twin Buttes Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	784	-----	-----
2	805	-----	-----
3	828	2,000	3,000
4	880	3,000	5,000
5	836	-----	-----
6	925	3,000	4,000
7	1,019	3,000	5,000
8	1,175	3,000	6,000
9	1,175	-----	-----
10	889	-----	-----
11	Empty	-----	-----
12	Empty	-----	-----
TOTAL		14,000	23,000

Lake Nasworthy

Lake Nasworthy is located immediately below Twin Buttes Reservoir in Area 2C and the combined yield of the two reservoirs works as an intergraded system. The conservation storage amounts to 12,000 acre-feet and is supplied by releases from Twin Buttes Reservoir. The total dissolved solids increase from 400 ppm to 890 ppm prior to the critical year of 2010, requiring an augmentation of 5,000 acre-feet or 8,000 acre-feet of 300 ppm or 500 ppm water, respectively. The increase in total dissolved solids during the critical year will be from 890 ppm to 1,310 ppm. By augmenting Twin Buttes Reservoir all water released to Lake Nasworthy will be at 800 ppm of total dissolved solids. This water in turn is evaporated causing an increase in minerals, and during the critical year an augmentation of 10,000 acre-feet or 16,000 acre-feet of 300 ppm or 500 ppm water, respectively, will be required. By the two reservoirs operating as an intergraded system, the amount of water in Lake Nasworthy is controlled and the conservation pool will be full at all times, causing all augmentation water to be spilled downstream, with the exception of the month of September when a high use allows the augmentation water to be retained in the reservoir. Table 3-C shows the month to month augmentation needs.

Table 3-C

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Nasworthy Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1] 300 ppm (AF/mo.)	Augmentation [1] 500 ppm (AF/mo.)
1	890	-----	-----
2	890	-----	-----
3	984	2,000	3,000
4	956	-----	-----
5	1,050	2,000	3,000
6	1,071	1,000	2,000
7	1,133	2,000	3,000
8	1,229	1,000	3,000
9	1,310	2,000	2,000
10	1,187	-----	-----
11	1,187	-----	-----
12	1,187	-----	-----
TOTAL		10,000	16,000

[1] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 5,000 acre-feet of 300 ppm total dissolved solids water or 8,000 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Colorado River

The Colorado River from river mile 153 to river mile 0 flows through Area 4 into the Gulf of Mexico. In this reach the return flows of Columbus, Eagle Lake, and Wharton, amounting to 48,000 acre-feet containing a biochemical oxygen demand load of 1,380 tons per year are received by the Colorado River. During the critical year, a deficiency in dissolved oxygen occurs in the months of January, February, March, October, and November. Irrigation diversions start in April and continue through September with sufficient amounts of return flows that augmentation is not required. An augmentation of 4,200 acre-feet will be required during the critical year to prevent a deficiency of dissolved oxygen. Table 4-C shows monthly requirements for this augmentation during critical year 2010.

Table 4-C

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Columbus Bend Reservoir To Tidewaters

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	2.8	3,000	590
2	3.3	3,000	440
3	2.1	3,000	1,110
4	7.7	76,000	-----
5	7.0	54,000	-----
6	6.7	119,000	-----
7	6.7	98,000	-----
8	6.7	62,000	-----
9	7.0	76,000	-----
10	2.7	4,000	1,290
11	2.7	3,000	770
12	4.4	4,000	-----

Total annual augmentation = 4,200 AF/yr.

SUMMARY SHEET
COLORADO RIVER BASIN

					Minerals				Dissolved Oxygen						
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed		Total Augmentation (DO &/or Minerals)		
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
Colorado			Lake J. B. Thomas	1/	485	688	--	--	--	--	--	--	--	--	TDS average for period.
	Morgan Creek		Lake Colorado City	2/	492	620	--	--	--	--	--	--	--	--	TDS average for period.
	Champion Cr.		Champion Cr. Res.	2/	377	415	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			Robt. Lee Res. M-730	1/	690	1,150	28,000	43,000	--	--	--	--	28,000	43,000	With correction for salt. Drouth extends through Apr. of succeeding year.
	Oak Creek		Oak Cr. Res.	1/	325	390	--	--	--	--	--	--	--	--	TDS average for period.
	Mid. & S. Concho		Twin Buttes Res.	1/	775	1,175	14,000 3/	23,000 4/	--	--	--	--	14,000	23,000	Augmentation prior to critical year not required.
	Mid. & S. Concho		Nasworthy Lake M-8	1/	890	1,310	10,000	16,000	--	--	--	--	10,000	16,000	Added 5,000 AF of 300 ppm prior to critical year or added 8,000 AF of 500 ppm prior to critical year.
	North Concho		San Angelo Res.	1/	287	342	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			Stacy Res., M-615	2/	406	345	--	--	--	--	--	--	--	--	TDS average for period.
		Hords Cr.	Hords Cr. Res.	5/	355	541	--	--	--	--	--	--	--	--	TDS average for period.
		Jim Ned & Hords	Camp Colorado Res.	6/	286	292	--	--	--	--	--	--	--	--	TDS average for period.
	Pecan Bayou & Jim Ned		Lake Brownwood M-57	5/	307	365	--	--	--	--	--	--	--	--	TDS average for period.
	Pecan Bayou		M-32 to M-14	5/	--	484	--	--	6.1	4.9	--	--	--	--	Brownwood return to Fox Crossing Reservoir.
Colorado			Fox Crossing Res.	6/	368	461	--	--	--	--	--	--	--	--	TDS average for period.
		Brady Cr.	Brady Reservoir	7/	354	382	--	--	--	--	--	--	--	--	TDS average for period.
	San Saba R.		San Saba Res.,M-46	6/	232	251	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			Buchanan Res.,M-413	6/	322	400	--	--	--	--	--	--	--	--	TDS average for period.

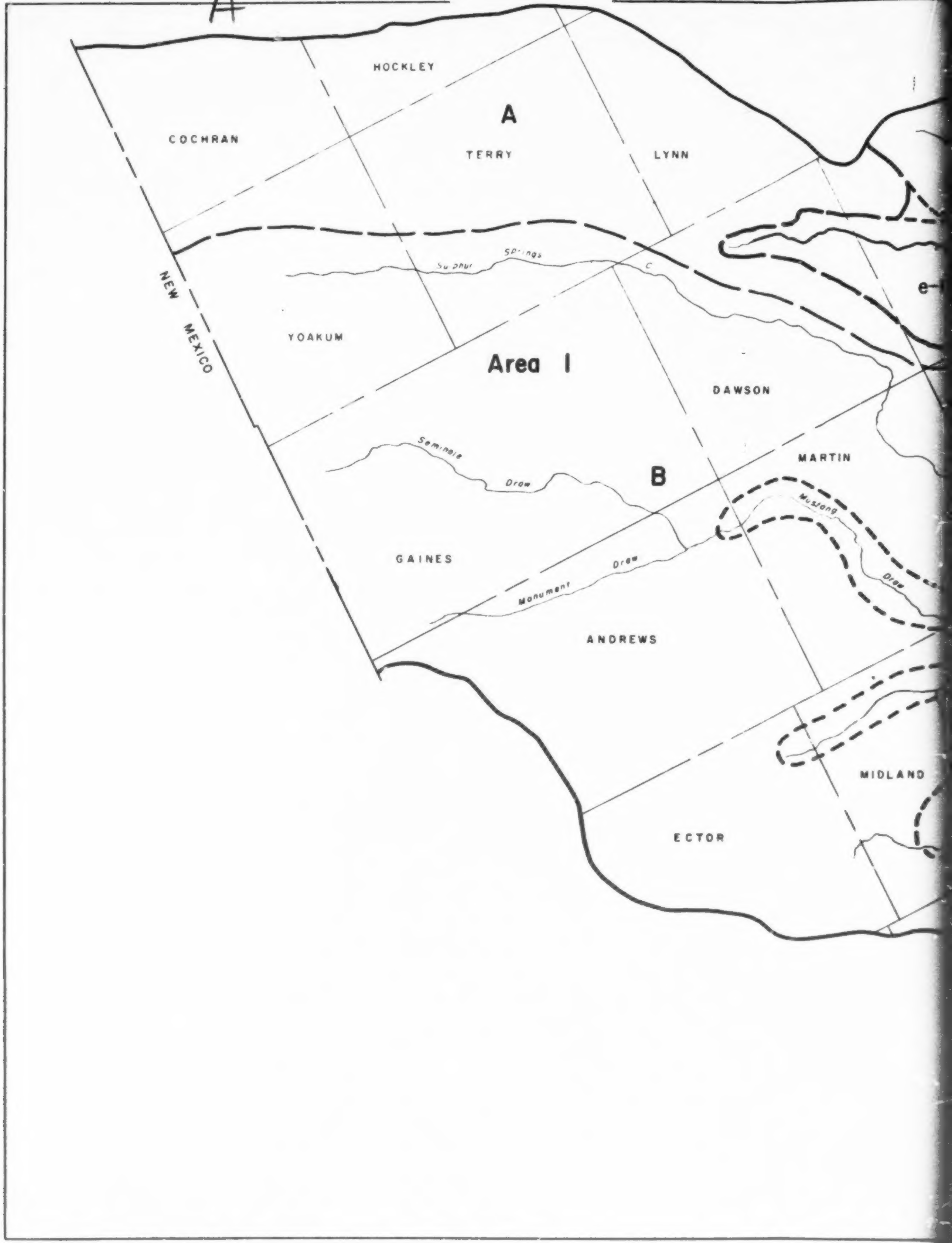
1/ The hydrologic critical year of 1952 projected for 2010 conditions.
2/ The hydrologic critical year of 1953 projected for 2010 conditions.
3/ Spill 2,000 AF of 300 ppm prior to critical year; spill 8,000 AF of 300 ppm during critical year.
4/ Spill 5,000 AF of 500 ppm prior to critical year; spill 14,000 AF of 500 ppm during critical year.
5/ The hydrologic critical year of 1950 projected for 2010 conditions.
6/ The hydrologic critical year of 1954 projected for 2010 conditions.
7/ The hydrologic critical year of 1948 projected for 2010 conditions.

SUMMARY SHEET (Continued)
COLORADO RIVER BASIN

River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Minerals: Crit. Year Conc. Start (ppm)	Minerals: Crit. Year Conc. During (ppm)	Minerals: Augmentation Needed 300 ppm (AF/yr)	Minerals: Augmentation Needed 500 ppm (AF/yr)	Dissolved Oxygen: Min. Conc. Reach (ppm)	Dissolved Oxygen: Min. Conc. Headwater (ppm)	Dissolved Oxygen: Augmentation Needed Reach (AF/yr)	Dissolved Oxygen: Augmentation Needed Headwater (AF/yr)	Total Augmentation (DO &/or Minerals) 300 ppm (AF/yr)	Total Augmentation (DO &/or Minerals) 500 ppm (AF/yr)	Remarks
	Llano River		Llano Reservoir	1/	249	265	--	--	--	--	--	--	--	--	TDS average for period.
	Pedernales		Pedernales Res.	1/	338	365	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			Travis Reservoir	1/	314	343	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			M-287 to M-201	1/	360	430	--	--	6.4	7.1	--	--	--	--	Austin return to LaGrange Reservoir.
Colorado			LaGrange Res.	1/	360	430	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			Columbus Bend Res.	1/	351	440	--	--	--	--	--	--	--	--	TDS average for period.
Colorado			M-153 to M-23	2/	--	665	--	--	2.1	1.5	4,200	--	4,200	4,200	Columbus Bend Res. to Tidewater. Augmentation made for reach.
Adjoining Area															
Lavaca			Edna Reservoir	2/	302	260	--	--	--	--	--	--	--	--	TDS average for period.
Lavaca			Vanderbilt Res.	2/	404	546	--	--	--	--	--	--	--	--	TDS average for period.
Lavaca	Navidad R.		Ganado Reservoir	2/	296	970	--	--	--	--	--	--	--	--	Augmentation not considered.
Lavaca	Navidad R.		Texana Reservoir	2/	371	580	--	--	--	--	--	--	--	--	TDS average for period.
Arenoso			Garcitas Res.	2/	344	435	--	--	--	--	--	--	--	--	TDS average for period.
Augmentation for Maintenance of Dissolved Oxygen Quality:													4,200	4,200	
Augmentation for Maintenance of Mineral Quality:													52,000	82,000	
Total:													56,200	86,200	

1/ The hydrologic critical year of 1954 projected for 2010 conditions.
2/ The hydrologic critical year of 1956 projected for 2010 conditions.

A


HOCKLEY
A
COCHRAN
TERRY
LYNN
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NEW MEXICO
YOAKUM
Area 1
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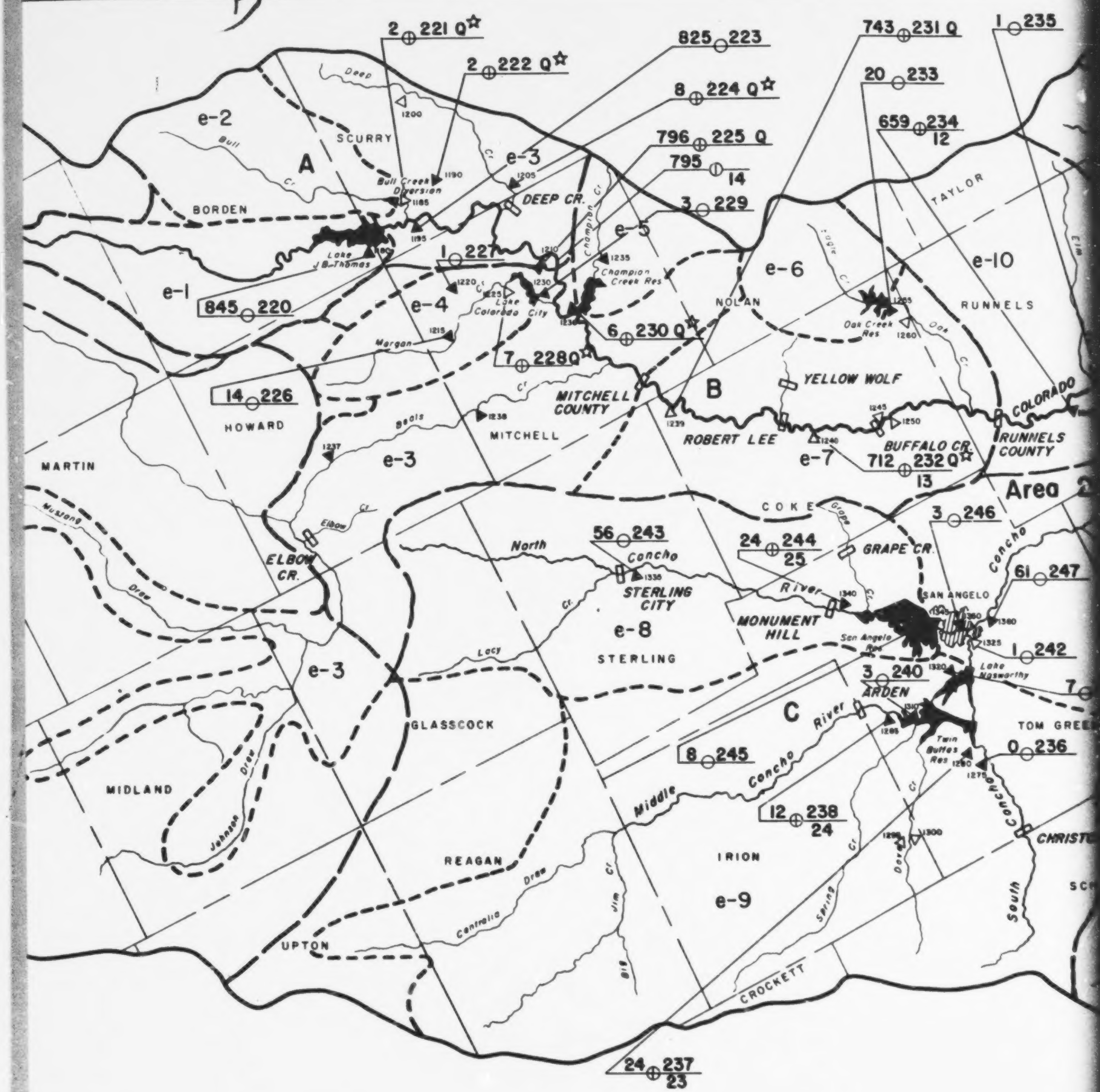
MARTIN
Seminole Draw
B
Mustang Draw
GAINES
Monument Draw
ANDREWS
MIDLAND
ECTOR

B


2 221 Q☆
2 222 Q☆
825 223
8 224 Q☆
796 225 Q
795 14
3 229
743 231 Q
1 235
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e-2
SCURRY
Deep
Bull Cr.
A
1200
1190
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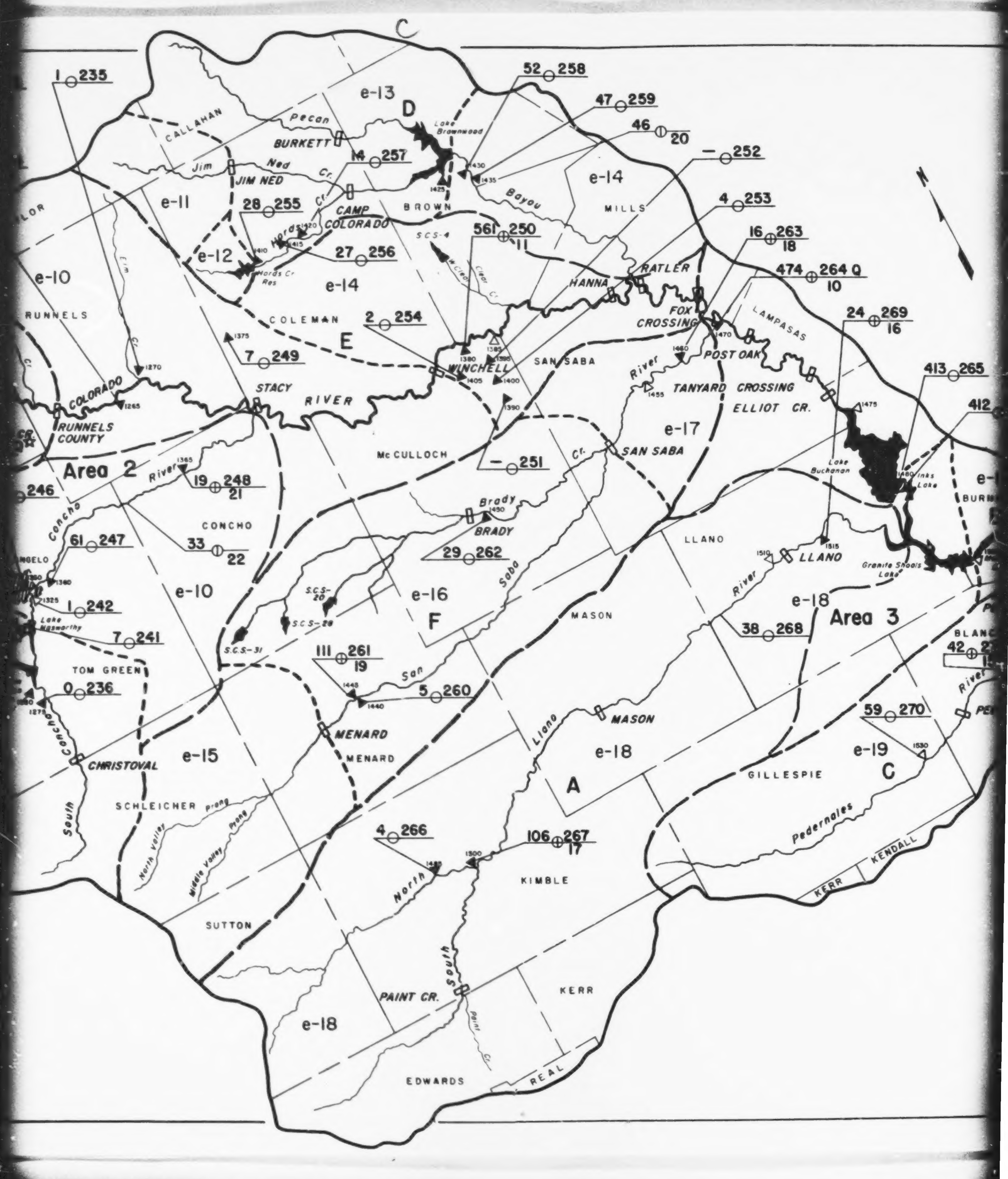
e-3
Bull Creek Diversion
1185
BORDEN
DEEP CR.
Champion Cr.
1195
1180
Lake J.B. Thomas
1210
1235
e-5
Champion Creek Res
1 227
e-1
845 220
1220
1225
Lake Colorado City
1230
1236
e-4
e-6
NOLAN
TAYLOR
e-10
RUNNELS
Oak Creek Res
1265
1260
Oak Cr.
6 230 Q☆
7 228 Q☆
1215
Morgan
14 226
HOWARD
Beals
1238
MITCHELL COUNTY
MITCHELL
B
1239
YELLOW WOLF
ROBERT LEE
1240
1245
1250
COLORADO
BUFFALO CR.
712 232 Q☆ 13
RUNNELS COUNTY
e-7
1237
e-3
MARTIN
Area 2
Mustang
Elbow Cr.
ELBOW CR.
Draw
COKE
Grape Cr.
GRAPE CR.
3 246
Concho
56 243
North Concho
24 244 25
1335
STERLING CITY
River
1340
MONUMENT HILL
SAN ANGELO
61 247
1345
1350
1360
1325
San Angelo Res
1 242
e-8
Cr.
STERLING
Lacy
e-3
3 240
ARDEN
Lake Nasworthy
1320
7
GLASSCOCK
C
River
1310
1285
Twin Buttes Res
1280
1275
TOM GREEN
0 236
8 245
Middle Concho River
MIDLAND
Johnson Draw
12 238 24
1295
1300
Dove Cr.
Spring Cr.
South Concho
CHRISTOVAL
REAGAN
IRION
e-9
Jim Cr.
Big
Centralia Draw
UPTON
SCH
CROCKETT
24 237 23


C
1 235
52 258
47 259
46 20
— 252
e-13
D
Lake Brownwood
CALLAHAN
Pecan
BURKETT
14 257
Jim
Ned
Cr.
JIM NED
e-11
BROWN
Bayou
e-14
MILLS
4 253
28 255
Cr.
Hords
CAMP COLORADO
27 256
S.C.S-4
561 250 11
16 263 18
e-12
Hords Cr Res
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e-14
RATLER
HANNA
474 264 Q 10
N
RUNNELS
COLEMAN
2 254
FOX CROSSING
LAMPASAS
24 269 16
E
7 249
WINCHELL
SAN SABA
POST OAK
River
TANYARD CROSSING
ELLIOT CR.
413 265
412
COLORADO
STACY
RIVER
RUNNELS COUNTY
McCULLOCH
— 251
Cr.
SAN SABA
e-17
Lake Buchanan
Inks Lake
Area 2
River
19 248 21
246
Concho
CONCHO
Brady
BRADY
LLANO
61 247
33 22
29 262
LLANO
Granite Shoals Lake
ANGELO
S.C.S-20
S.C.S-28
e-16
Saba
1 242
e-10
Lake Nasworthy
F
MASON
e-18
Area 3
7 241
S.C.S-31
38 268
111 261 19
San
TOM GREEN
0 236
5 260
42
59 270
River
Concho
CHRISTOVAL
MENARD
MENARD
e-15
Llano
MASON
e-18
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A
C
South
SCHLEICHER
prong
GILLESPIE
North Valley
Middle Valley Prong
Pedernales
4 266
106 267 17
KENDALL
North
KIMBLE
KERR
SUTTON
South
PAINT CR.
KERR
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EDWARDS
REAL

D

COLORA

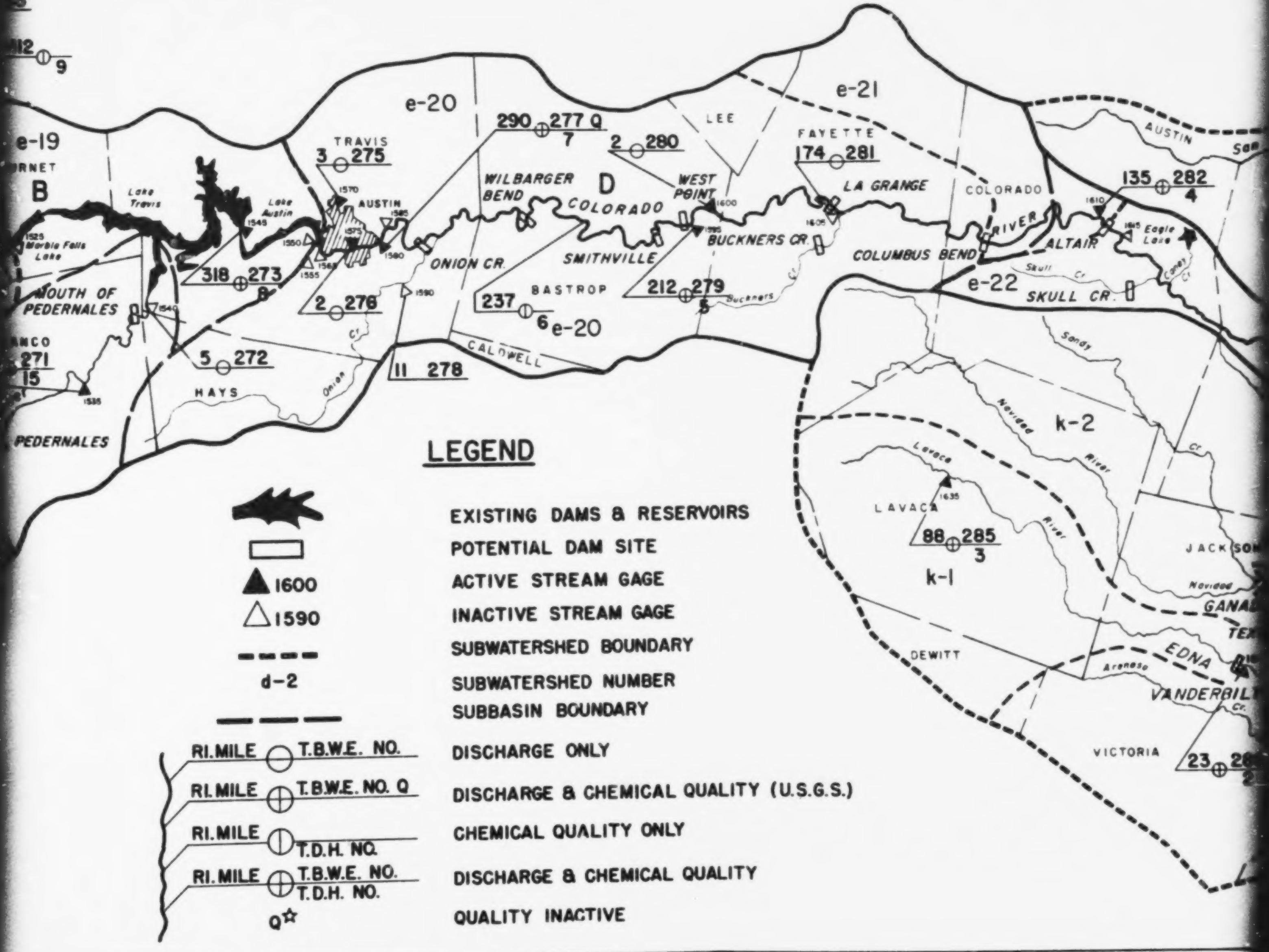
DISCHARGE & QUAL

U. S. D

HEALTH, ED

PUBLIC

REGION VII



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B
D
BURNET
TRAVIS
LEE
FAYETTE
AUSTIN
COLORADO
BASTROP
CALDWELL
HAYS
LAVACA
DEWITT
VICTORIA
JACKSON
Lake Travis
Lake Austin
Marble Falls Lake
MOUTH OF PEDERNALES
PEDERNALES
AUSTIN
WILBARGER BEND
COLORADO
WEST POINT
LA GRANGE
BUCKNERS CR.
SMITHVILLE
ONION CR.
COLUMBUS BEND
RIVER
ALTAIR
SKULL CR.
Eagle Lake
EDNA
VANDERBILT
GANAD
Navidad River
Lavaca River
Sandy Cr.
Arenosa Cr.
312 9
318 273 8
3 275
2 276
5 272
271 15
290 277 Q 7
2 280
237 6
11 278
212 279 5
174 281
135 282 4
88 285 3
23 28 2
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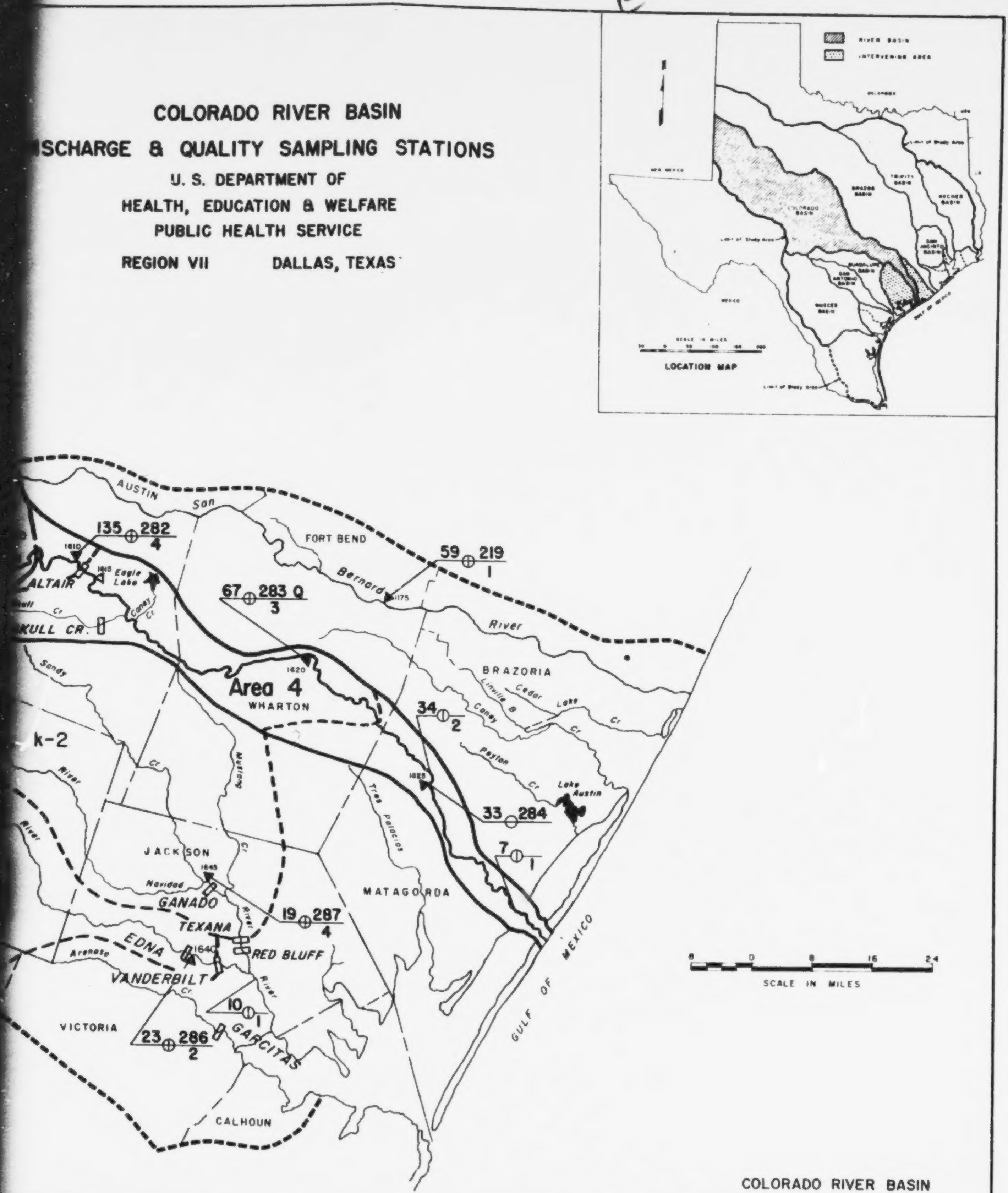
1595
1600
1605
1610
1615
1635
LEGEND
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
1600 ACTIVE STREAM GAGE
1590 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T.B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE

E

COLORADO RIVER BASIN
ISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS



RIVER BASIN
INTERVENING AREA
NEW MEXICO
COLORADO BASIN
BRAZOS BASIN
TRINITY BASIN
NECHES BASIN
SAN JACINTO BASIN
GUADALUPE BASIN
SAN ANTONIO BASIN
NUECES BASIN
MEXICO
Limit of Study Area
GULF OF MEXICO
SCALE IN MILES
50 0 50 100 150 200
LOCATION MAP
AUSTIN
San
FORT BEND
Bernard
River
135 282 4
59 219 1
67 283 Q 3
1610
1615
Eagle Lake
ALTAIR
Cr
Coney Cr
KULL CR.
1175
BRAZORIA
Sandy
1620
Area 4
WHARTON
Linville B
Cedar Lake Cr
Cr
Caney
34 2
k-2
River
Cr
Mustang
Peyton Cr
Lake Austin
1625
Tres Palacios
33 284
7 1
River
JACKSON
Cr
1645
Navidad
GANADO
MATAGORDA
River
19 287 4
TEXANA
EDNA
1640
RED BLUFF
Arenosa
VANDERBILT
Cr
River
10 1
VICTORIA
23 286 2
GARCITAS
CALHOUN
GULF OF MEXICO
8 0 8 16 24
SCALE IN MILES

COLORADO RIVER BASIN

68-A

FIGURE NO. C-1

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE GUADALUPE RIVER BASIN

The Guadalupe River rises on the Edwards Plateau in south-central Texas and flows generally southeastward 446 miles to San Antonio Bay. The principal tributary streams are Johnson Creek, the Comal and San Marcos Rivers, Peach Creek, Sandies Creek, and Coleto Creek. The river drains a total of 6,000 square miles, with the slope of the river having four breaks in its fall of 1,930 feet.

River Mile	Slope
0 to 235	1.6 ft. per mile
235 to 280	3.8 ft. per mile
280 to 405	6.9 ft. per mile
405 to 446	12.2 ft. per mile

The present development of the basin consists of four reservoirs of 5,000 acre-feet or greater capacity. Of the four reservoirs, three are used for hydroelectric power. The fourth, Canyon Dam, is now under construction and will have 366,400 acre-feet of conservation storage.

The proposed plan for the projected needs of the basin calls for six new reservoirs in the basin proper with two additional reservoirs located in the adjoining area. The combined added conservation storage amounts to 6,433,000 acre-feet.

The quality analysis consists of individual studies on seven reservoirs and three separate reaches. The study shows that high mineral content in reservoirs and reaches will be the main source of pollution in the basin. One reach of the river below Seguin will have a deficiency in dissolved oxygen. The mineral content of the same reach will be excessive and the augmentation needs for minerals will be controlling. The total needs of the basin will be 72,900 acre-feet of 300 ppm water or 121,650 acre-feet of 500 ppm water.

Lockhart Reservoir

Lockhart Reservoir is located in Area 3 on the upper reaches of Plum Creek. The conservation storage is 30,000 acre-feet which will yield 3,300 acre-feet per year. Since return flows do not enter the reservoir, the high increase in total dissolved solids is caused by evaporation. In the period preceding the critical year of 2010, the total dissolved solids increase from 410 ppm to 1,060 ppm and will require 6,000 acre-feet or 10,000 acre-feet of 300 ppm or 500 ppm water, respectively, of augmentation water. During the critical year, the minerals increase from 1,060 ppm to 3,960 ppm without augmentation and will require 6,700 acre-feet or 11,150 acre-feet of 300 ppm or 500 ppm augmentation to maintain the water quality objective of 800 ppm.

Table 1-G shows the monthly requirements for augmentation.

Table 1-G

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Lockhart Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1] 300 ppm (AF/mo.)	Augmentation [1] 500 ppm (AF/mo.)
1	1,088	-----	-----
2	1,119	400	650
3	1,207	900	1,500
4	1,182	-----	-----
5	1,241	500	850
6	1,417	1,000	1,650
7	1,714	1,200	2,000
8	2,222	1,200	2,000
9	2,670	600	1,000
10	3,240	600	1,000
11	3,960	300	500
12	3,390	-----	-----
TOTAL		6,700	11,150

[1] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 6,000 acre-feet of 300 ppm of total dissolved solids water or 10,000 acre-feet of 500 ppm of total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control

San Marcos River

The San Marcos River, a tributary of the Guadalupe, flows through Area 3 and drains 1,380 square miles of the basin. The two main tributaries are the Blanco River, joining the San Marcos at river mile 77, and Plum Creek, entering the river at mile 19. The river starts at the San Marcos Springs which release into the river 25,000 acre-feet of water through the critical year. During the critical year of 2010, the return flows from the city of San Marcos reduces the dissolved oxygen to a minimum of 4.0 ppm, which is the water quality criteria, and augmentation flows are not needed.

An investigation shows that oil field brines are being released to Plum Creek, causing the total dissolved solids to exceed 2,000 ppm. By correcting this and similar problems, the mineral content can be reduced to 500 ppm of total dissolved solids. Assuming that Plum Creek has been corrected, the maximum of 3,220 ppm of total dissolved solids during the critical year of 2010 would result from irrigation return flows. This high mineral content will require 9,000 acre-feet of augmentation if water of 300 ppm total dissolved solids can be obtained. Table 2-G shows the monthly requirements for water quality of water used for improvement.

Table 2-G

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, San Marcos River

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	515	-----	-----
2	470	-----	-----
3	1,320	1,000	1,500
4	2,220	3,000	5,000
5	3,220	3,000	5,000
6 [1]	-----	-----	-----
7 [1]	-----	-----	-----
8 [1]	-----	-----	-----
9	1,550	2,000	3,500
10 [1]	-----	-----	-----
11	670	-----	-----
12	430	-----	-----
TOTAL		9,000	15,500

[1] At mile 250 stream goes dry due to diversions.

Guadalupe River

The first reach of the Guadalupe River flows from the lower section of Area 2, through Area 4, a small part of Area 3, and all of Area 5 into Cuero Reservoir. In this distance of approximately 140 miles, the river receives the return flows of New Braunfels and Seguin, as well as, irrigation return flows amounting to 19,600 acre-feet of treated municipal waste with a biochemical oxygen demand load of 370 tons and 12,700 acre-feet of irrigation returns per year. During the critical year of 2010, a deficiency in dissolved oxygen occurs at about river mile 250. The deficiency in dissolved oxygen will require 6,800 acre-feet of augmentation for the year to maintain the water quality objective of 4.0 ppm of dissolved oxygen in the reach. Table 3-G shows the monthly requirements for the augmentation.

Table 3-G

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, Guadalupe River

	Critical Point on Reach Without Augmentation for Qualtiy		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	5.0	2,600	-----
2	4.9	2,600	-----
3	1.6	10	310
4	1.0	410	350
5	0.0	410	840
6	0.0	410	1,010
7 [1/]	0.4	500	980
8 [1/]	0.0	400	1,030
9	0.0	400	870
10	0.7	400	820
11	1.5	400	370
12	5.0	2,600	-----

Total annual augmentation = 6,780 AF/yr.

[1/] At mile 250 stream goes dry due to diversions.

In this same reach of the river, the high mineral load in the irrigation return flows causes the total dissolved solids to increase to 3,140 ppm during the critical year of 2010. This increase in minerals will require 14,000 acre-feet or 23,500 acre-feet of 300 ppm or 500 ppm augmentation water, respectively. By augmenting for the high mineral content above the confluence of the San Marcos River, the deficiency of dissolved oxygen in the same reach will be augmented and the 6,800 acre-feet would not be required. Table 4-G shows the monthly breakdown of the required mineral augmentation.

Table 4-G

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Guadalupe River

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation 300 ppm (AF/mo.)	Augmentation 500 ppm (AF/mo.)
1	500	-----	-----
2	450	-----	-----
3	2,800	1,500	2,500
4	2,480	1,500	2,500
5	2,920	1,500	2,500
6	3,140	2,000	3,000
7	2,340	1,500	2,500
8	2,700	1,500	2,500
9	2,480	1,500	2,500
10	2,330	2,000	3,000
11	2,250	1,000	2,500
12	450	-----	-----
TOTAL		14,000	23,500

The second reach of the Guadalupe River flows through all of Area 6 into Confluence Reservoir. Treated municipal waste from Cuero and Victoria are received by the river, along with irrigation returns. The analysis shows that there will not be a deficiency in dissolved oxygen but irrigation returns will cause the minerals to increase to 950 ppm of total dissolved solids during the critical year. To maintain the water quality objective of 800 ppm, 38,200 acre-feet or 63,700 acre-feet of 300 ppm or 500 ppm augmentation water will be required. This amount of augmentation is a minimum that will be required for river. Area 6 "Others" has a high tonnage of minerals in its return flow, which is not accounted for in the operations and could materially change the augmentation requirements; therefore, monthly augmentations have not been computed.

Beeville Reservoir

Beeville Reservoir is located on Medio Creek, a tributary to Mission River in the adjoining area of the Guadalupe River. The reservoir will have a reported conservation storage of 64,000 acre-feet with a yield of 4,000 acre-feet supplying the municipal and industrial needs of the city of Beeville. The streams draining into the reservoir do not receive any return flows; however, prior to and during the critical year, the mineral content of the reservoir builds up due to evaporation. The evaporation ranges from 5,000 acre-feet to 13,000 acre-feet per year. In the period preceding the critical year of 2010, the total dissolved solids increase from 365 ppm to 1,235 ppm and will require 11,000 acre-feet of 300 ppm or 18,500 acre-feet of 500 ppm augmentation water. During the critical year the mineral content increases from 1,235 ppm to 2,780 ppm requiring 5,000 acre-feet or 8,300 acre-feet of 300 ppm or 500 ppm augmentation water to maintain the water quality objective of 800 ppm of total dissolved solids. Table 5-G shows monthly requirements for the augmentation.

Table 5-G

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Beeville Reservoir

Month	Maximum Mineral Concentraion Without Augmentation For Quality (ppm)	Augmentation [1/] 300 ppm (AF/mo.)	Augmentation [1/] 500 ppm (AF/mo.)
1	1,235	-----	-----
2	1,235	-----	-----
3	1,411	1,500	2,500
4	1,411	-----	-----
5	1,271	-----	-----
6	1,482	500	800
7	1,851	1,500	2,500
8	2,780	1,500	2,500
9	2,780	-----	-----
10	2,780	-----	-----
11	2,780	-----	-----
12	1,528	-----	-----
TOTAL		5,000	8,300

[1/] It should be noted that the need for augmentation in this case assumes that prior to the beginning of the critical year, quality was controlled by the addition of 11,000 acre-feet of 300 ppm of total dissolved solids water or 18,500 acre-feet of 500 ppm of total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

Blanco Reservoir

The Blanco Reservoir is located on Blanco Creek, a tributary to Mission River in the adjoining area of the Guadalupe River. The reservoir will have a reported 53,000 acre-feet of conservation storage and will yield 5,000 acre-feet per year for municipal, industrial, and irrigation uses.

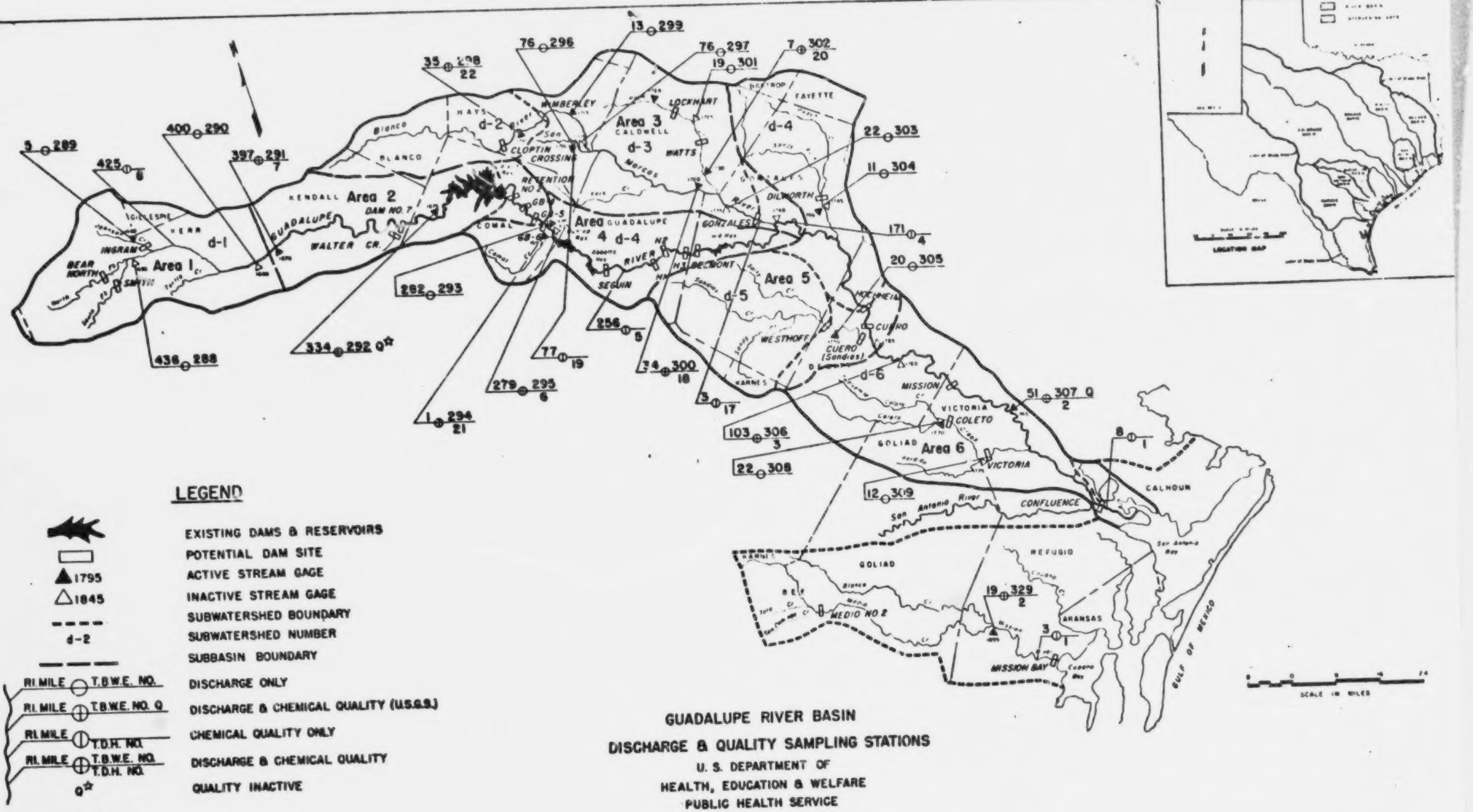
An analysis of the reservoir shows that the minerals will increase to 860 ppm during the critical year of 2010. The increase in minerals would require some augmentation; however, the amount was not computed due to the yield being allocated for use in the lower portion of the Gulf Coast area which receives its water through the proposed canal. Operations for the canal are not available and this small amount of water would have very little effect on the quality of the total water in the canal.

SUMMARY SHEET
GUADALUPE RIVER BASIN

					Minerals				Dissolved Oxygen				Total Augmentation (DO &/or Mineral)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Head-water (ppm)	Reach (AF/yr)	Head-water (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
Guadalupe	Johnson Cr.		Ingram Reservoir	(1)	360	370	--	--	--	--	--	--	--	--	TDS average for period.
Guadalupe			Canyon Reservoir	(1)	405	475	--	--	--	--	--	--	--	--	TDS average for period.
Guadalupe	San Marcos R.	Blanco R.	Cloptin Cross. Res.	(1)	397	409	--	--	--	--	--	--	--	--	TDS average for period.
		Plum Cr.	Lockhart Res.	(1)	1,060	3,960	6,700	11,150	--	--	--	--	6,700	11,150	Added 6,000 AF of 300 ppm prior to critical year or added 10,000 AF of 500 ppm prior to critical year.
	San Marcos R.		M-77 to M-0	(1)	--	3,220	9,000	15,000	4.0	--	--	--	9,000	15,000	TDS average for period.
Guadalupe			M-303 to M-163	(1)	--	3,140	14,000	23,500	0.0	0.0	6,800	--	14,000 2/	23,500 2/	Total is for mineral augmentation only. Headwaters Cuero Reservoir.
Guadalupe			Cuero Reservoir)	(1)	648	794	--	--	--	--	--	--	--	--	TDS average for period.
	Sandies Cr.		Sandies Reservoir)	(1)	648	794	--	--	--	--	--	--	--	--	TDS average for period.
Guadalupe			M-109 to M-37	(1)	--	950	38,200	63,700	6.1	5.4	--	--	38,200	63,700	TDS average for period.
Guadalupe			Confluence Res.	(1)	Operation data furnished incomplete.										
Adjoining Area - Mission River															
Mission	Medio Cr.		Beeville Res.	(1)	1,235	2,780	5,000	8,300	--	--	--	--	5,000	8,300	Added 11,000 AF of 300 ppm prior to critical year. Added 18,500 AF of 500 ppm prior to critical year.
Mission	Blanco Cr.		Blanco Res.	(1)	750	860	--	--	--	--	--	--	--	--	Augmentation not considered.
											Total:		72,900	121,650	
					Augmentation for Maintenance of Dissolved Oxygen Quality:								--	--	
					Augmentation for Maintenance of Mineral Quality:								72,900	121,650	
					Total:								72,900	121,650	

(1) The hydrologic critical year of 1956 projected for 2010 conditions.

(2) This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.


LEGEND
EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
1795 ACTIVE STREAM GAGE
1845 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
d-2 SUBWATERSHED NUMBER
SUBBASIN BOUNDARY
RI. MILE T.B.W.E. NO. DISCHARGE ONLY
RI. MILE T.B.W.E. NO. Q DISCHARGE & CHEMICAL QUALITY (U.S.G.S.)
RI. MILE T.D.H. NO. CHEMICAL QUALITY ONLY
RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
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Area 2
Area 3
Area 4
Area 5
Area 6
d-1
d-2
d-3
d-4
d-5
d-6
KENDALL
GILLESPIE
KERR
BLANCO
HAYS
COMAL
CALDWELL
GUADALUPE
GONZALES
FAYETTE
BASTROP
KARNES
DE WITT
GOLIAD
VICTORIA
REFUGIO
ARANSAS
CALHOUN
BEAR NORTH
INGRAM
SANTOS
GUADALUPE
WALTER CR.
DAM NO. 7
RETENTION NO. 2
CLOPTIN CROSSING
WIMBERLEY
LOCKHART
WATTS
DILWORTH
SEGUIN
RIVER
BELMONT
WESTHOFF
CUERO (Sandies)
CUERO
HOCHHEIM
MISSION
COLETO
VICTORIA
CONFLUENCE
San Antonio River
MEDIO NO. 2
MISSION BAY
San Antonio Bay
GULF OF MEXICO
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400 290
397 291 7
436 288
334 292 Q☆
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279 295 6
77 19
256 5
34 300 18
3 17
103 306 3
22 308
12 309
51 307 Q 2
8 1
19 329 2
3 1
SCALE IN MILES
LOCATION MAP

GUADALUPE RIVER BASIN

DISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

GUADALUPE RIVER BASIN

FIGURE NO. 8-1

77-A

U.S. STUDY COMMISSION-TEXAS 6 58

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE SAN ANTONIO RIVER BASIN

The San Antonio River flows in a southeasterly direction and is bounded on the north and east by the Guadalupe River and on the west by the Nueces River. The river basin is small (4,200 square miles of drainage), with the river having a total length of about 237 miles. At river mile 210, the Medina River, a tributary to the San Antonio River extends for an additional 90 miles.

The profile of the river has a total fall of approximately 665 feet, not considering the fall of the tributary, Medina River, and consists of three distinct slopes.

River Mile	Slope
0 to 70	1.2 ft. per mile
70 to 205	2.3 ft. per mile
205 to 237	8.75 ft. per mile

The 111 miles of the main reach of the river from the city of San Antonio to Goliad is subject to and will become polluted by a total deficiency of dissolved oxygen under the projected condition for the year 2010.

The present development of the basin consists of three reservoirs of 5,000 acre-feet or more, with an addition of four more proposed for full development of the basin by the year 2010.

The quality analysis starts with Medina Reservoir and extends throughout the basin to the headwaters of Confluence Reservoir and includes individual studies of four reservoirs and two reaches of the main stem of the river. The deficiency of dissolved oxygen caused by the treated municipal waste returns of the city of San Antonio, amounting to approximately 99 percent of the biochemical oxygen demand load, is the principal source of pollution in the San Antonio River. The water quality objective of 4.0 ppm of dissolved oxygen will require 212,180 acre-feet of augmentation.

San Antonio River

The San Antonio River reach located in Areas 2 and 4 comprises a large portion of the entire river, from river mile 222 to the headwaters of Goliad Reservoir, river mile 111.

The city of San Antonio is the main contributory to the flow in the river, the return flow amounting to 333,500 acre-feet per year with a biochemical oxygen demand loading of 11,040 tons. During the critical year of 2010 the river became completely deficient in oxygen at about river mile 191, regaining back to 1.7 ppm of dissolved oxygen at the headwaters of Goliad Reservoir.

The dissolved oxygen conditions vary through the year, with the river going into a septic condition during the months of May through August. To maintain the water quality objective of 4.0 ppm of dissolved oxygen during the critical year an augmentation of 212,180 acre-feet will be required. Table 1-SA shows the monthly requirements for this augmentation.

Table 1-SA

Critical Year Forecast of Organic Quality and Augmentation Flows Required to Maintain 4.0 ppm Dissolved Oxygen Only, San Antonio River

	Critical Point on Reach Without Augmentation for Quality		
Month	Minimum Dissolved Oxygen (ppm)	Flow (AF/mo.)	Augmentation Required (AF/mo.)
1	3.3	23,660	3,050
2	2.7	22,280	5,890
3	2.1	22,740	8,770
4	1.2	22,280	14,000
5	0.0	22,280	27,660
6	0.0	21,820	30,590
7	0.0	22,280	30,160
8	0.0	22,740	34,990
9	0.4	24,580	28,730
10	1.5	25,500	17,430
11	2.1	22,740	8,770
12	3.5	22,100	2,140

Total annual augmentation = 212,180 AF/yr.

Goliad Reservoir

Goliad Reservoir is located in Area 4 and receives the full effect of all return flows in the basin. The reservoir has a reported conservation storage of 983,000 acre-feet and during the critical period, by releases for use downstream and evaporation, the conservation storage is reduced to 18,100 acre-feet. The mineral content during the critical year increases to 830 ppm of total dissolved solids. Without water quality control upstream, in the San Antonio River, an annual augmentation of 24,000 acre-feet or 38,800 acre-feet of 300 ppm or 500 ppm water will be required. However, with the high amounts of augmentation needed upstream for dissolved oxygen control, additional augmentation in the reservoir will not be required, and with the drawdown of the conservation pool the added flow from augmentation will not exceed the total conservation storage during the critical year and spills will not occur.

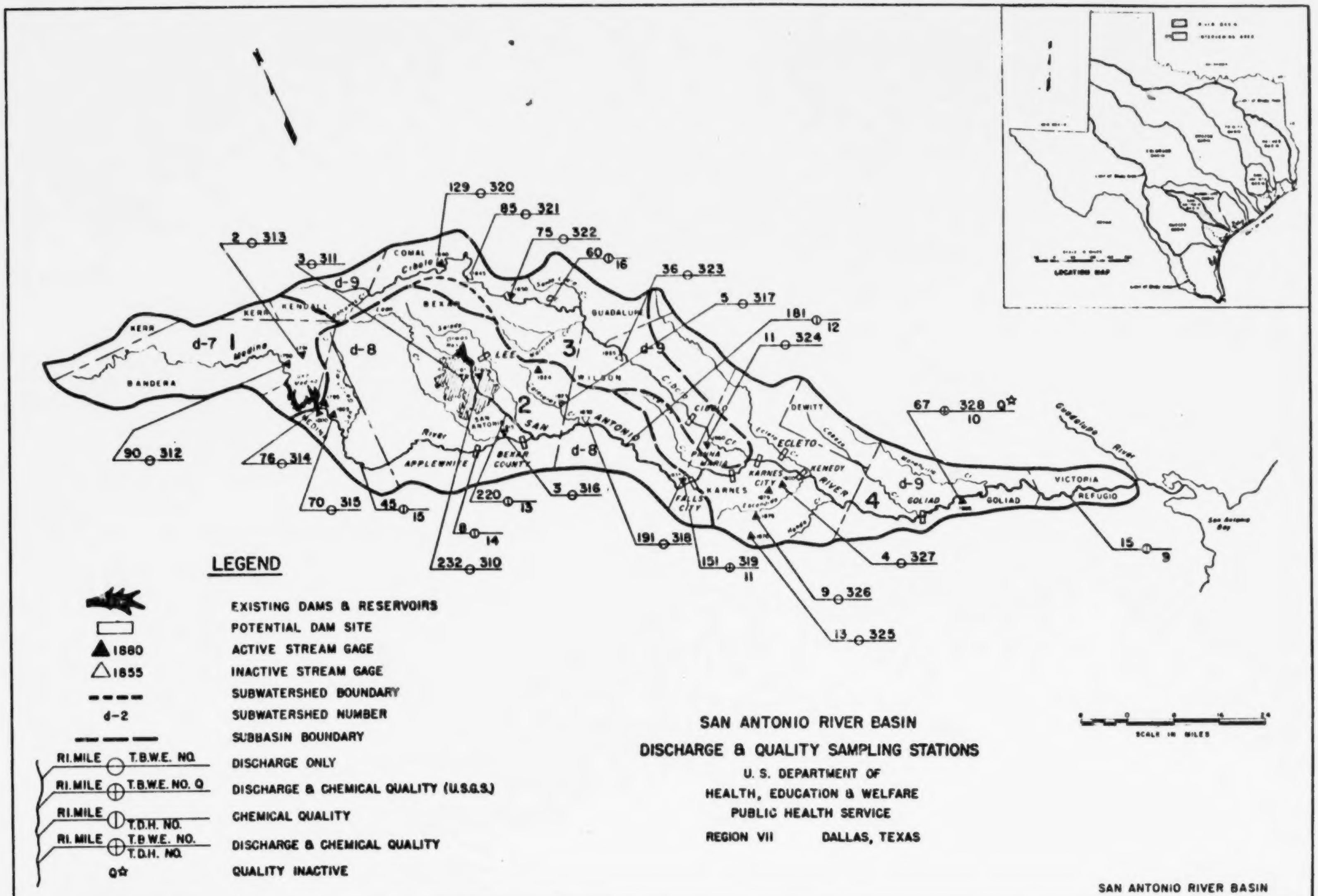
Irrigation returns downstream from Goliad Reservoir increase the total dissolved solids to 836 ppm. During the critical year the releases from the reservoir have been reduced in mineral content by the augmentation upstream and the irrigation returns will have very little effect upon the river.

SUMMARY SHEET
SAN ANTONIO RIVER BASIN

River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Minerals: Crit. Year Conc. Start (ppm)	Minerals: Crit. Year Conc. During (ppm)	Minerals: Augmentation Needed 300 ppm (AF/yr)	Minerals: Augmentation Needed 500 ppm (AF/yr)	Dissolved Oxygen: Min. Conc. Reach (ppm)	Dissolved Oxygen: Min. Conc. Headwater (ppm)	Dissolved Oxygen: Augmentation Needed Reach (AF/yr)	Dissolved Oxygen: Augmentation Needed Headwater (AF/yr)	Total Augmentation (DO &/or Mineral) 300 ppm (AF/yr)	Total Augmentation (DO &/or Mineral) 500 ppm (AF/yr)	Remarks
	Medina River		Medina Reservoir	1/	350	385	--	--	--	--	--	--	--	--	
San Antonio			M-222 to M-111	1/	--	770	--	--	0.0	0.0	212,180	--	212,180	212,180	Headwaters, Goliad Res.
	Cibolo Creek		Cibolo Reservoir	1/	510	460	--	--	--	--	--	--	--	--	TDS average for period.
	Ecleto Creek		Ecleto Reservoir	1/	627	637	--	--	--	--	--	--	--	--	TDS average for period.
San Antonio			Goliad Reservoir	1/	762	830	24,000	38,800	--	--	--	--	0 2/	0 2/	TDS average for period.
San Antonio			M-65	1/	--	830	--	--	--	--	--	--	--	--	TDS average for period.
San Antonio			M-40	1/	--	836	--	--	--	--	--	--	--	--	TDS average for period.
Augmentation for Maintenance of Dissolved Oxygen Quality:													212,180	212,180	
Augmentation for Maintenance of Mineral Quality:													0	0	
Total													212,130	212,130	(Mineral augmentation not included in total.)

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

2/ This is not simple addition of individual components. The total includes adjustments for water quality of one component resulting from augmentation for maintenance of quality of other component.


LEGEND
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POTENTIAL DAM SITE
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RI. MILE T.B.W.E. NO. T.D.H. NO. DISCHARGE & CHEMICAL QUALITY
Q☆ QUALITY INACTIVE
KERR
BANDERA
KENDALL
COMAL
BEXAR
GUADALUPE
WILSON
KARNES
DEWITT
GOLIAD
VICTORIA
REFUGIO
BEXAR COUNTY
SAN ANTONIO
FALLS CITY
KARNES CITY
KENEDY
ECLETO
CIBOLO
Cibolo
APPLEWHITE
Medina
MEDINA
River
RIVER
Guadalupe River
San Antonio Bay
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d-8
d-9
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4
2 313
3 311
129 320
85 321
75 322
60 16
36 323
5 317
181 12
11 324
67 328 Q☆ 10
15 9
4 327
9 326
13 325
151 319 11
191 318
232 310
8 14
220 13
3 316
45 15
70 315
76 314
90 312
SCALE IN MILES
LOCATION MAP

SAN ANTONIO RIVER BASIN

DISCHARGE & QUALITY SAMPLING STATIONS

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

SAN ANTONIO RIVER BASIN

U S STUDY COMMISSION-TEXAS SA 35

81-A

FIGURE NO. SA-1

FUTURE QUALITY OF WATER IN RESERVOIRS AND REACHES IN THE NUECES RIVER BASIN

The Nueces River Basin lies entirely within southeastern Texas, rising on the Edwards Plateau in Real County. The river flows generally to the southeast, draining 17,000 square miles of area, for a total distance of 446 river miles and empties into Nueces Bay northwest of Corpus Christi. The two major tributaries are the West Nueces and Frio Rivers. In its entire length the river falls 2,200 feet. This fall has two major slopes.

River Mile	Slope
0 to 342	1.8 ft. per mile
342 to 446	15.3 ft. per mile

The present development consists of two reservoirs in the basin of 5,000 acre-feet or greater capacity and four reservoirs in the adjoining area of 5,000 acre-feet or greater capacity, with only one, Lake Corpus Christi, serving municipal and industrial needs. The proposed maximum development of the basin will have 11 new reservoirs and an enlargement of the existing Lake Corpus Christi. Four of the new reservoirs will be located in the adjoining areas.

An analysis was made on a total of 10 reservoirs for mineral quality. The study shows that all reservoirs within the basin will maintain a quality of good to satisfactory. In the adjoining area Bayside Reservoir on the Arkansas River will exceed the water quality objective of 800 ppm of total dissolved solids.

In the period preceding the critical year of 2010, the total dissolved solids increase from 276 ppm to 1,700 ppm and will require 35,000 acre-feet of augmentation using 300 ppm water or 58,500 acre-feet using 500 ppm water. During the critical year, the total dissolved solids increase from 1,700 ppm to a maximum of 14,770 ppm. An increase of this amount will require 16,000 acre-feet, or 26,000 acre-feet of 300 ppm, or 500 ppm water, respectively. The high build-up of total dissolved solids is caused by evaporation ranging from 12,000 acre-feet to 31,000 acre-feet per year, very little runoff during the critical period, and the reservoir going virtually dry in December of the critical year from municipal and industrial use. Table 1-Nu shows the monthly augmentation needs.

Table 1-Nu

Critical Year Forecast of Mineral Quality and Augmentation Flows Required to Maintain 800 ppm of Total Dissolved Solids Only, Bayside Reservoir

Month	Maximum Mineral Concentration Without Augmentation For Quality (ppm)	Augmentation [1] 300 ppm (AF/mo.)	Augmentation [1] 500 ppm (AF/mo.)
1	1,700	-----	-----
2	1,832	1,500	3,000
3	1,730	-----	-----
4	1,872	1,000	2,000
5	1,891	1,000	2,000
6	2,300	3,000	5,000
7	2,975	3,000	5,000
8	4,400	3,500	5,000
9	6,080	1,500	2,000
10	6,080	-----	-----
11	14,770	1,500	2,000
12	3,585	-----	-----
TOTAL		16,000	26,000

[1] It should be noted that the need for augmentations in this case assume that prior to the beginning of the critical year quality was controlled by the addition of 35,000 acre-feet of 300 ppm total dissolved solids water or 58,500 acre-feet of 500 ppm total dissolved solids water. Maximum mineral concentrations are those which would occur if no action is taken to provide water for quality control.

The organic quality of the entire basin and adjoining areas will be satisfactory. This is based on the operations furnished for analysis, which do not return any treated municipal waste and irrigation return flows to the river. All return flows are assumed to be consumed in channel losses or used for irrigation of minor areas, with the exception of return flows from the coastal area which are returned to tidewater.

An investigation shows that there is a possible source of radioactive pollution in the upper reaches of Atascosa River. While it is not known whether the river is polluted, future investigation and analysis should be made to determine the extent that radioactive wastes could pollute the river.

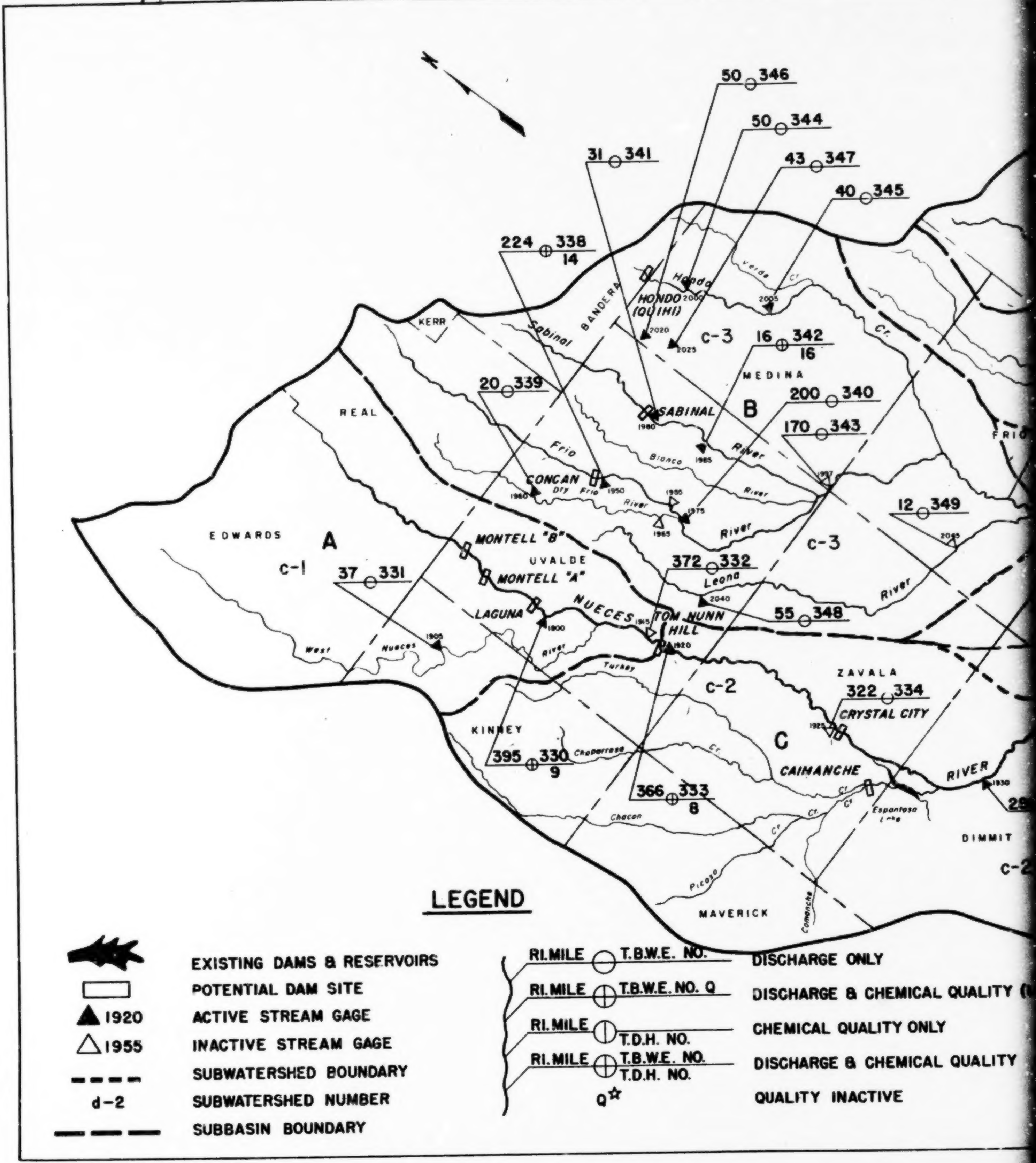
The total augmentation needs of the basin and adjoining area are 16,000 acre-feet for 300 ppm or 26,000 acre-feet for 500 ppm water required for the high minerals in Bayside Reservoir.

SUMMARY SHEET
NUECES RIVER BASIN

					Minerals				Dissolved Solids				Total Augmentation (DO &/or Minerals)		
					Crit. Year Conc.		Augmentation Needed		Min. Conc.		Augmentation Needed				
River	Tributary	Second Tributary	Study and/or River Mile	Critical Year	Start (ppm)	During (ppm)	300 ppm (AF/yr)	500 ppm (AF/yr)	Reach (ppm)	Headwater (ppm)	Reach (AF/yr)	Headwater (AF/yr)	300 ppm (AF/yr)	500 ppm (AF/yr)	Remarks
Nueces			Crystal City Res.	1/	323	320	--	--	--	--	--	--	--	--	TDS average for period.
	Caimanche Cr.		Caimanche Reservoir	1/	404	473	--	--	--	--	--	--	--	--	TDS average for period.
Nueces			Cotulla Reservoir	1/	668	449	--	--	--	--	--	--	--	--	TDS average for period.
	Frio River		Concan Reservoir	1/	293	383	--	--	--	--	--	--	--	--	TDS average for period.
		Sabinal R.	Sabinal Reservoir	1/	285	308	--	--	--	--	--	--	--	--	TDS average for period.
	Frio River		Fowlerton Reservoir	1/	365	355	--	--	--	--	--	--	--	--	TDS average for period.
	Frio River		Choke Canyon Res.	1/	660	686	--	--	--	--	--	--	--	--	TDS average for period.
Nueces			Lake Corpus Christi	1/	457	674	--	--	--	--	--	--	--	--	TDS average for period.
Adjoining Area															
Aransas R.			Woodsboro Reservoir	1/	406	443	--	--	--	--	--	--	--	--	TDS average for period.
Aransas R.			Bayside Reservoir	1/	1,700	14,770	16,000	26,000	--	--	--	--	16,000	26,000	Added 35,000 AF of 300 ppm prior to critical year. Added 58,500 AF of 500 ppm prior to critical year.
			Augmentation for Maintenance of Mineral Quality:										16,000	26,000	

1/ The hydrologic critical year of 1956 projected for 2010 conditions.

A



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KERR
BANDERA
HONDO (QUIHI)
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Verde Cr.
Cr.
Sabinal
MEDINA
REAL
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B
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Frio
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River
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Dry Frio River
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A
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MONTELL "B"
UVALDE
MONTELL "A"
LAGUNA
NUECES
TOM NUNN HILL
Leona
West Nueces River
Turkey
c-2
ZAVALA
CRYSTAL CITY
KINNEY
C
Chaparrosa Cr.
CAIMANCHE
RIVER
Espantosa Lake
Chacon Cr.
Picoso
Comanche
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EXISTING DAMS & RESERVOIRS
POTENTIAL DAM SITE
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1955 INACTIVE STREAM GAGE
SUBWATERSHED BOUNDARY
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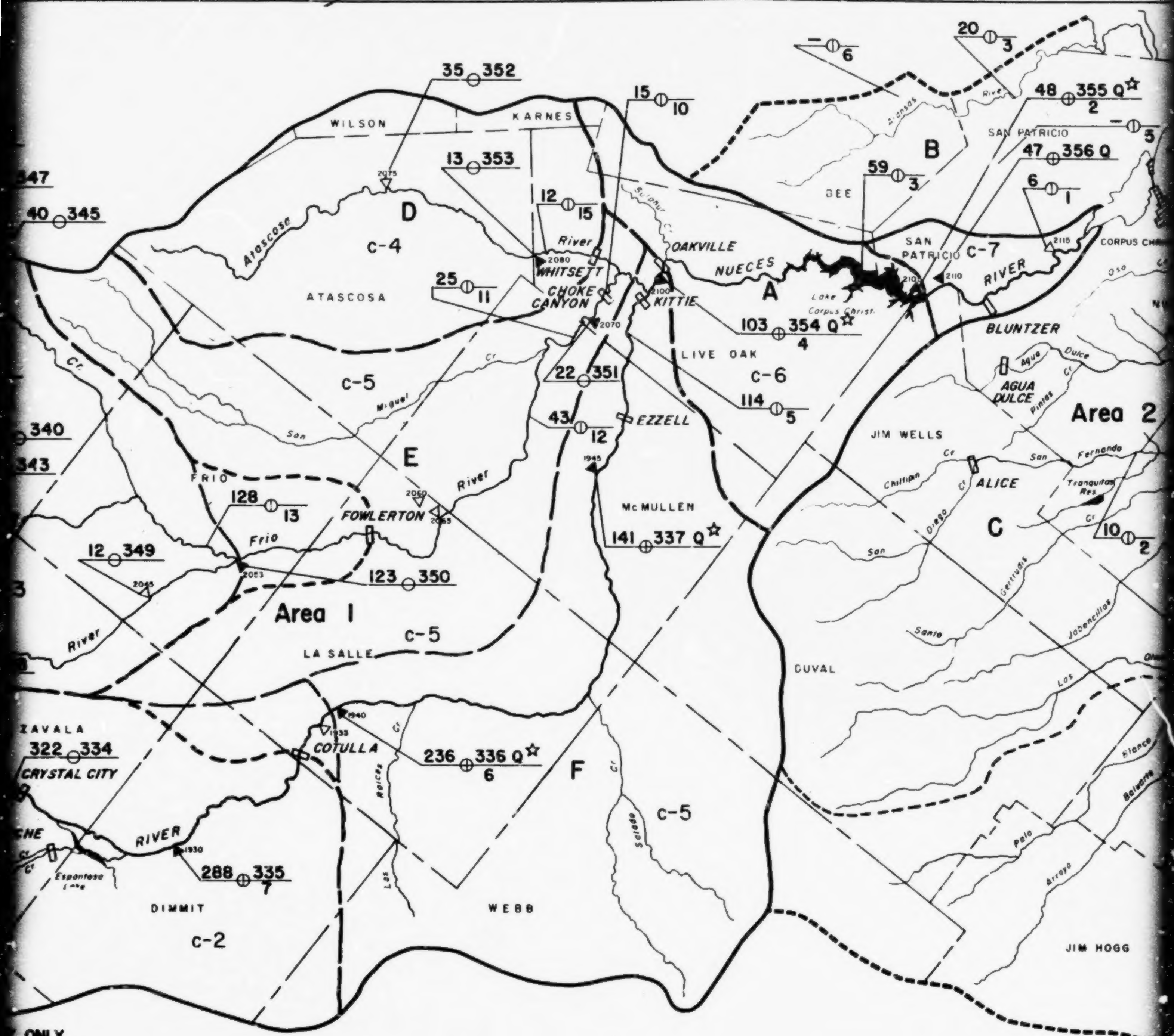
Q☆ QUALITY INACTIVE

US STUDY COMMISSION-TEXAS NU 55

B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Lake Corpus Christi
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DUVAL
Los Olmos
ZAVALA
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Espantosa Lake
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Arroyo
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WEBB
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JIM HOGG

ONLY

& CHEMICAL QUALITY (U.S.G.S.)

QUALITY ONLY

& CHEMICAL QUALITY

NACTIVE

NUECES RIVER BASIN

DISCHARGE & QUALITY SAMPLING STATION

U. S. DEPARTMENT OF
HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

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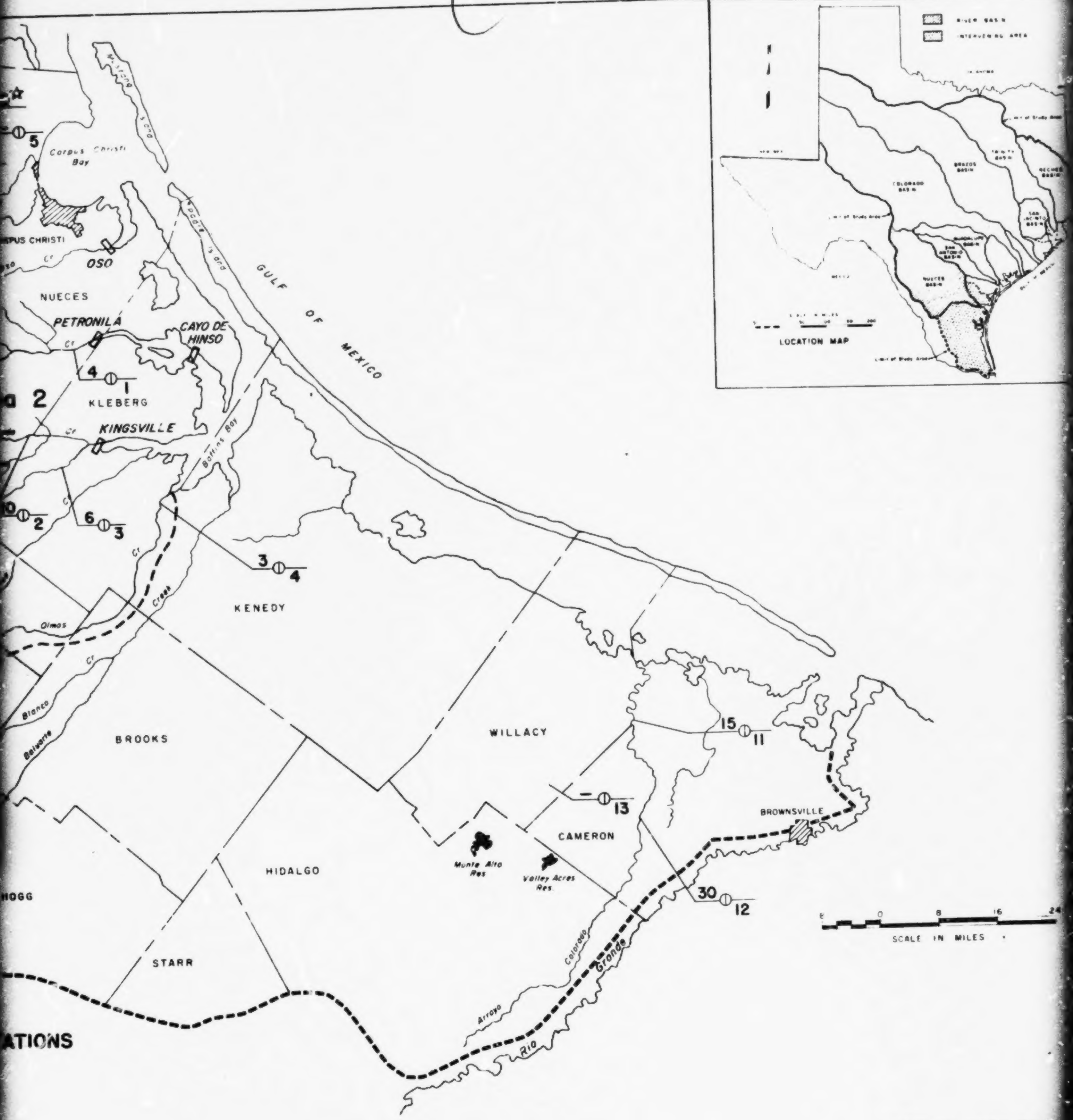
Corpus Christi Bay
CORPUS CHRISTI
OSO
NUECES
PETRONILA
CAYO DE HINSO
KLEBERG
KINGSVILLE
Baffins Bay
Mustang Island
Padre Island
GULF OF MEXICO
KENEDY
BROOKS
WILLACY
CAMERON
HIDALGO
STARR
HOGG
Monte Alto Res
Valley Acres Res.
BROWNSVILLE
Olmos Creek
Blanco Cr
Baluarte
Arroyo Colorado
Rio Grande
5
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30 12
SCALE IN MILES
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LOCATION MAP
RIVER BASIN
INTERVENING AREA
COLORADO BASIN
BRAZOS BASIN
TRINITY BASIN
NECHES BASIN
SAN JACINTO BASIN
GUADALUPE BASIN
SAN ANTONIO BASIN
NUECES BASIN
Limit of Study Area
ATIONS

NUECES RIVER BASIN

FIGURE NO.

85-A